

Project Title: "Use of Climate-Information Products by Water Managers and Other Stakeholders in Two GCIP/GAPP Watersheds in Arizona/Sonora and Oklahoma"¹

NOAA grant number: NAO30AR4310149

Time period covered: 1 August 2003 to 31 July 2007

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¹ The Oklahoma portion of this grant was awarded under a separate contract to USDA/ARS; the foregoing report pertains only to work undertaken by the University of Arizona team.

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I. PROPOSED EFFORT

A. Project abstract

Building upon previous research and outreach efforts in the San Pedro basin (Arizona/Sonora) and Washita/Red-Arkansas basin (Oklahoma), we proposed a three-year project (which was extended at no cost to four years in 2006) to continue and expand our efforts to (1) assess climate information products/tools for water management, (2) find ways to narrow the communication gap between climate experts and information users, and (3) improve ways to integrate the science of climate with public policy. The San Pedro basin, where the work was initially focused, was designated, with the support of the GEWEX Water Resource Applications Project (WRAP), as a HELP¹ Demonstration Basin (the most advanced, and accordingly, most in tune with the principles and aims of HELP, of four categories). The proposed work was intended to expand the body of research related to the theoretical and practical aspects of the role of climate information for water management, stakeholder decisionmaking, and public policy, and build upon the contributions from regional climate impacts and vulnerability assessments, particularly those focused on water basins. The portion of the proposal that addressed the Washita/Red-Arkansas basin (Oklahoma), which is also a HELP basin, was given independent status in 2004.

B. Objective of research project

1. Assess products and tools

- Assess status of available climate information useful in a transboundary (U.S.-Mexico) context.
- Obtain evaluation of transboundary climate information from stakeholders.
- Determine product usability, accuracy, and utility in interaction with natural-resource/water stakeholders/managers.
- Identify potential opportunities to transfer North American Monsoon Experiment (NAME) products into transboundary settings:
 - Using archival information and surveys, analyze trends in demographics, institutional changes, water management, economic growth, and land use/land tenure arrangements.
 - Using focus group and workshop techniques, assess need for/use of climate information.
 - Introduce stakeholders to climate forecasts and related information through structured workshop settings; use structured workshop interactions, as well as follow-up surveys, as needed, to obtain feedback on utility, usability, and perceived accuracy of the information provided.
 - Conduct structured analysis of results of focus groups, workshops, and surveys to assess climate perceptions and how these are linked with decisions/actions.
 - Using a decision support system (DSS) model developed by Kevin Lansey, develop an assessment of the sensitivity of water resources on Mexican side of border to climate variability (assuming sufficient data are available to conduct the analysis). Using the results of surveys and focus groups, assess the capacity of basin residents to design and implement adaptive management strategies that reduce/avert vulnerability to climatic stresses.

2. Bridge communications gap

- Narrow knowledge and communications gaps between climate researchers/products and area stakeholders.
- Identify areas where improvements in climate products could be made and provide feedback to climate scientists/forecasters:

¹ Hydrology for the Environment, Life and Policy—a global water initiative comprising about 70 watersheds around the world, whose administrative headquarters have been at UNESCO's International Hydrological Programme in Paris, France.

- Conduct preliminary focus groups to ascertain how participants define and view climate, identify the types of climate conditions that pose the greatest concern, as well as the greatest potential benefit to area residents and to identify current coping mechanisms.
- Hold capacity-building workshops in the use and interpretation of climate information with watershed councils or climate and resource focus groups.
- Link local southwestern Oklahoma land and water agencies with the ARS Grazing Lands Research Lab and Oklahoma University's Mesonet.
- Establish a regional coordinator/facilitator in southwestern Oklahoma to promote the collaboration of federal and state water agencies, tribes and local landowners on regional water, climate, and land use issues.

3. Integrate science and policy

- Assess the potential impacts of climate variability and change on water policy, economic development, and land management/land use practices.
- Identify promising avenues for introducing science into policymaking.
- Identify innovative ways to link stakeholders with forecasters and forecast models for the interface between land use, climate and hydrology.
- Assess the potentials and constraints of using the watershed-council framework and water focus groups for integrating science and policy.
 - Investigate land tenure, soil and water management in Mexican portion of the San Pedro for policy implications under conditions of climate variability and change.
 - Carry out a structured assessment of the results of the research conducted in this project to determine extent to which science is already integrated into policy structures and the potential for/barriers to introduction of climate information into such processes.
 - Identify changes that must be made in organizational, institutional, and professional frameworks in order to increase the integration of science into policy making and implementation processes, including enhanced participation of community members in scientific research as well as increased outreach from scientists to residents of the region.

C. Approach

1. Assess products and tools

- Using archival information and surveys, analyze trends in demographics, institutional changes, water management, economic growth, and land use/land tenure arrangements.
- Using focus group and workshop techniques, assess need for/use of climate information.
- Introduce stakeholders to climate forecasts and related information through structured workshop settings; use structured workshop interactions, as well as follow-up surveys, as needed, to obtain feedback on utility, usability, and perceived accuracy of the information provided.
- Conduct structured analysis of results of focus groups, workshops, and surveys to assess climate perceptions and how these are linked with decisions/actions.
- Using the DSS model developed by Dr. Kevin Lansey, assess the sensitivity of water resources on Mexican side of border to climate variability (assuming sufficient data are available to conduct the analysis) and evaluate impacts of climate change projections on the hydrology of the San Pedro basin (AZ) using emission scenarios. Drawing on the results of surveys and focus groups, assess the capacity of basin residents to design and implement adaptive management strategies that reduce/avert vulnerability to climatic stresses.

2. Bridge communications gap

- Conduct preliminary focus groups to ascertain how participants define and view climate, identify the types of climate conditions that pose the greatest concern, as well as the greatest potential benefit to area residents and to identify current coping mechanisms.

- Hold capacity-building workshops in the use and interpretation of climate information with watershed councils or climate and resource focus groups.
- Establish a regional coordinator/facilitator in southwestern Oklahoma to promote the collaboration of federal and state water agencies, tribes and local landowners on regional water, climate, and land-use issues.

3. Integrate science and policy

- Investigate land tenure, soil and water management in Mexican portion of the San Pedro for policy implications under conditions of climate variability and change.
- Carry out a structured assessment of the results of the research conducted in this project to determine extent to which science is already integrated into policy structures and the potential for/barriers to introduction of climate information into such processes.
- Identify changes that must be made in organizational, institutional, and professional frameworks in order to increase the integration of science into policy making and implementation processes, including enhanced participation of community members in scientific research as well as increased outreach from scientists to residents of the region.
- Include range of results in DSS model to support water management in the basin.

II. DEVIATIONS FROM PROPOSAL²

Rather than include this discussion within the Accomplishments section below—which would tend to obscure the modifications to the workplan—we are presenting this before the report on work done.

In the first annual progress report (June 2004), we highlighted the difficulty of assessing information on climate variability in real time. We also noted the cross-border disparity in availability of information and expertise. And, we indicated implicitly that on both sides of the border, for different reasons, attention to climate-related issues does not enjoy widespread priority among either decisionmakers or other stakeholders. These challenges persist and will not soon dissipate.

During the 2004-05 year, the project team experienced a set of previously unfelt constraints. Beginning just before the end of the first project reporting period, a significant set of political developments occurred in the Mexican portion of the San Pedro basin. Notwithstanding the research team's longstanding and well-received presence, experience, collaborative relationships, and record of accomplishment in Sonora, larger forces came into play.

The project's aim to foster greater understanding and acceptance of integrating climate forecasting with water management, and to do this via community-based water councils, was met with varying degrees of wariness. At the most local level, our efforts were supported by several community groups such as a then-incipient environmental NGO (nongovernmental organization), ARASA (Sonora-Arizona Regional Environmental Association) and by officials of the municipalities of Cananea and Naco. But historic differences of opinion surfaced between on the one hand, the strong Cananea-based mining interests and their state government supporters, and on the other hand, environmental groups such as ARASA. Compounding this dynamic, regional officials of the Mexican national water commission (CONAGUA, formerly CNA) expressed concern that only officially-designated watershed councils were authorized to operate in the area (none has yet been so designated for the San Pedro). Additionally, the highly centralized CONAGUA defines its priorities nationally, leaving small, lightly-populated basins such as the San Pedro poorly funded and without influential champions. Even at the regional level, CONAGUA in Sonora simply does not consider the San Pedro among its highest priorities, given its range of more pressing needs and demands from larger urban and major agricultural areas. Adding to the uncertainty, after more than a decade of increasing closeness between Mexico and the United States, the events of 9/11 and its aftermath have resulted in distinctly cooler relations—a state of affairs that has palpably affected transborder cooperation. And finally, the situation is further complicated by the fact that a very significant presidential election is coming up in mid-2006. It is not clear what the new leadership will be,

² Except for the part titled "Postscript," below, this section is drawn from the 2004 and 2005 interim reports.

and how much of the Fox/Zedillo reforms will be carried through by the new administration—in particular, in regard to water councils and formalized public participation.

In such a context, those aspects of the project that could be seen as going beyond mere research (as expressed in the opening sentence of the preceding paragraph) were interpreted by some as uninformed involvement in the affairs of another nation. The manifestations of this new attitude were mostly subtle and certainly not overtly hostile, but it became clear that our investigators could not easily attend official meetings, interview key personnel, or gain access to such relevant information as exists. This situation may have eased somewhat in recent months and we have perceived a shift toward more openness on the part of CONAGUA and others to our research entrees. This leads us to believe that things are moving in a positive direction. Nevertheless, given the lifetime of the grant, we may not be able to capitalize on these improvements to the extent we would have a year earlier.

Meanwhile, in Arizona, on the U.S. side of the border, much of the responsibility for managing the San Pedro basin has accrued to the Upper San Pedro Partnership (USPP). The USPP, over the past six or seven years has become the dominant force in the U.S. portion of the upper part of the watershed. With strong congressional and state support, this alliance of more than 20 agencies and NGOs has grown and gained respect. In the past year, the USPP was charged by the U.S. Congress with responsibility for assuring the sustainability of water in the basin.

Over the years, the Udall Center has been instrumental in the formation and maturation of the USPP and one of the project co-PIs, David Goodrich, is an influential member of the Partnership. In addition, we have co-authored numerous scientific and policy-oriented papers with members of the USPP. As a result, the research team has maintained excellent relations with the USPP and its leadership. The USPP has been highly receptive to attempts by the project, especially during the first year, to build binational, cross-border institutional relationships (as noted in the first interim report). But because of the past year's developments, we have decided to postpone further promotion of such linkages, which could be seen as unnecessarily intrusive. The chief constraint we have felt has been the relatively cautious approach taken by the USPP in regard to use and integration of climate forecasting tools in its water management planning activities.

Accordingly, in September 2004 the project team met and decided to redirect some of its activities—in particular, those tasks that could not be undertaken in the present climate (and we note here that we had already accomplished a great deal of fieldwork prior to the shift in relations, so that overall the impact of the political shift was muted somewhat). As a basis for the revision, the PI and co-PIs agreed, insofar as possible, to retain the overarching objectives of the project, namely to, (1) assess products and tools, (2) attempt to bridge the communications gap, and (3) work to integrate science and policy.

In 2004 the research team leadership resolved to reconfigure the project's activities as follows:

- Continue to convene, attend, and participate in relevant meetings on both sides of the border, while solidifying relationships with policymakers, managers, and other stakeholders.
- Identify appropriate, distinct, achievable research papers to be jointly-authored and submitted to peer-reviewed journals.
- Highlight the scientific aspects of the project, which seem to be more attractive to Mexican officials and others than the pursuit of policy-related objectives, most specifically by developing a prototype "Climate Outlook" package for the U.S.-Mexico border area modeled on CLIMAS's product for the southwestern United States, and by collaborating on the use of decision-support tools.
- Address the communications gap via new curriculum development efforts.
- In all these undertakings, redouble our resolve to work closely with Mexican colleagues, especially in the academic sector, thus alleviating the perception of external interference in Mexican domestic affairs while strengthening our credibility and building strong research alliances.

The team further concluded that the political developments that occasioned the changes, while unanticipated and problematic, also presented a good opportunity to analyze and write about those

developments. The situation clearly offers particular insights into politics, water decisionmaking, and agenda-setting in Mexico as well as more general lessons that could be of use elsewhere.

Encouraged by the success of the collaboration with CLIMAS on the Climate Outlook prototype for Mexico, beginning in July 2005, the project team determined to greatly strengthen its connections to other regional NOAA projects and to other cross-border, climate-related efforts. Thus, this project began working much more closely with the Physical Sciences Division (formerly Climate Diagnostics Center) of NOAA's Earth Systems Research Laboratory, the Western Water Assessment RISA, the NCAR Research Applications Laboratory, and the North American Monsoon Experiment (NAME).

At the same time, we came to realize more pointedly than before that to achieve success regionally—in Sonora, where our political problems were most manifest—we needed to link ourselves more strongly to federal agencies, officials, and researchers in the area of Mexico's capital. Over the past 11 months, we have therefore greatly enhanced our collaborations with Mexico's National Meteorological Service (SMN); National Water Commission (CONAGUA); the two binational transboundary water commissions, the Comisión Internacional de Límites y Agua (CILA) and its U.S. counterpart, the International Boundary and Water Commission (IBWC); and key research institutions such as the National Institute for Water Research (IMTA); the National Autonomous University (UNAM); and other academic centers such as CISESE and COLEF in Baja California, ITSON, COLSON, and UNISON in Sonora. Through a series of meetings and workshops and a conference, we are now much better integrated into the larger climate-research/climate-product-delivery network.

In Sonora itself, contact with high level Mexican CONAGUA officials and with representatives of the Sonora State Water Commission confirmed the complex nature of Mexican water-and-climate policy and practice—especially in transboundary settings. According to CONAGUA officials, water is owned by the Mexican federal government on behalf of the nation and therefore cannot be the subject of state or local transboundary planning. Nonetheless, it should be noted that several forms of collaboration on transboundary watersheds do exist along the U.S.-Mexico border: the Tijuana River Watershed, the Mimbres basin, and, to a lesser degree, the Río Bravo-Rio Grande River basin (New Mexico Water Resources Institute and Centro de Información Geográfica for the Paseo del Norte). In addition, the CILA actively encourages transboundary watershed collaboration, including the binational support and use for 12 computer planning models (presentation, Arturo Herrera Solis, Mexican CILA commissioner, May 22-24, 2006). Still, intergovernmental uncertainty about the process of decentralizing Mexican watershed management and climate-information management makes it a challenge to work in this one sector in a truly transboundary manner.

Meanwhile, on the U.S. side of the border in Arizona, in spring 2006, the USPP drafted a Long-Range Planning Document for 2006–2011, reinforcing their effort to “apply the best available science and engineering both to defining the challenges and in evaluating solutions.” One of these tools is a Decision Support System (DSS) model, developed partly by project researchers Aleix Serrat Capdevila and Anne Browning-Aiken, working with Drs. Kevin Lansey, Juan Valdes, and other colleagues elsewhere at the University of Arizona. Thanks to the present project, this DSS model contains—for the first time—*climate* as well as water-management components, which the USPP now employs to establish alternative management scenarios.

In addition, on the Mexican side of the border, both the Colegio de Sonora (COLSON) and the University of Sonora (UNISON) have expressed interest in adapting this DSS model for application in northern Sonora. Through various presentations, seminars, workshops, and other programs, researchers at the Udall Center and SAHRA have introduced Mexican students and water managers to the model and given them the opportunity to test it by exploring alternative management strategies.

Postscript, October 26, 2007

Over the past three years, as the preceding section has made clear, the Northwest Sector Office of Mexico's National Water Commission (CONAGUA) has been reluctant to participate in binational planning efforts for the Upper San Pedro Basin. From a Mexican national standpoint, this resistance to working binationally was understandable since (a) there is no treaty covering such collaboration, (b) Mexico's traditional centralized approach to governance is different from the more decentralized Arizona model, and (c) water problems in Central Mexico have greater impact and therefore are accorded much higher priority than issues in the northern border region.

Nevertheless, in spite of the difficulties of enlisting the interest of CONAGUA, the research team has persisted in working with local water managers and city officials, as well as with the Colegio of Sonora and the University of Sonora. We have continued to collaborate with our Mexican colleagues on climate and water issues. This strategy has been intended to further the objectives of this project by linking scientific efforts to meet the needs of water managers, local stakeholders, and other decision-makers in the basin.

Based on very recent developments, our persistent attempts to promote collaboration among the Arizona and Sonora communities and supporting academic researchers have apparently begun to have an impact.

With a new federal administration in place in Mexico City, CONAGUA has just unveiled a major change of water policy for the border region. The San Pedro was declared one of three northern basin to receive an official watershed association, known in Mexico as a *Consejo de Cuenca*. This group of stakeholders, appointed by CONAGUA, called the Comisión de Cuenca Del Río San Pedro, would play an important role in water governance in the region, in keeping with the spirit of Mexico's recently changed water law. Going even further, the Commission recognized the transboundary nature of the San Pedro basin and declared the Consejo to be Mexico's first *binational* watershed council.

In recognition of our project's influential role in promoting such a stakeholder-oriented development, three members of the team (Browning-Aiken, Serrat-Capdevila, and Scott) were invited by CONAGUA to attend the inauguration of the Binational San Pedro Commission on October 24, 2007. They were received cordially by national and regional officials of CONAGUA, city officials, and local representatives of industrial, agricultural, and ranching sectors. They were invited to be partners in a new effort to form a binational basin team.

In effect, the project team now has a seat at the table, with Browning-Aiken as a non-voting member of the new commission. Other representatives from the U.S. will include members of the Upper San Pedro Partnership, Arizona governmental and non-governmental representatives, and University of Arizona researchers to exchange information, data, technology, and planning ideas.

As the director of the Mexican National Water Commission (CONAGUA), Northwest Sector Office, commented, the binational San Pedro Commission is an exemplary showcase for Mexico. This effort has the support of the Mexican government, including the borderlands office for CONAGUA. In short, we believe this is a precedent that opens up the possibility of carrying out the objectives we started with three years ago.

III. ACCOMPLISHMENTS

A. Research tasks

Bridge communications gap, promote scientific cooperation, and integrate science and policy—Solidifying relationships with policymakers, managers, and other stakeholders

1. Assessing the landscape. Sonoran climate variability survey, “Climate, Water Management, and Policy in the San Pedro Basin: Results of a Survey of Mexican Stakeholders Near the U.S.-Mexico Border”

The survey, conducted in 2003 and 2004, produced a concrete vision, mission and goals, as well as a time line and tangible strategies to be followed in this study. Data research and collection in a variety of Mexican, U.S. and international sources, as well as participation in U.S.-and Mexico- based Climate workshops / forums. The study is also monitoring and assessing different sources of climate information. For this purpose, alliances with U.S. (NOAA) and Mexican Climate experts (CICESE, DICTUS, UNAM) have been forged to provide a comprehensive and integrated data collection and interpretation. Data collection focuses on climate variables (precipitation, temperature, stream flow, soil humidity) from southern Arizona and northern Sonora, that will facilitate the assessment of climate variability in the Sonoran desert biome and in particular in the transitional area of the Upper San Pedro River Basin.

Under the auspices of the Dialogue on Water and Climate and NOAA, water and climate surveys assess the quality and usability of climate and hydrologic information available to water managers and communities in the Mexican portion of the San Pedro River Basin. The surveys indicate that the central concern for urban residents is the lack of reliable potable-water due to frequent service breakdowns—with climate change and variability, specifically drought and high temperatures, as contributing factors. Water managers desire appropriate meteorological and hydrologic information to improve planning strategies, but access to this information remains limited. Considerable disagreement exists about who should pay for previously free or low-cost water and wastewater treatment. Urban users have little incentive to conserve because of the flat low rate and frustration with service. In rural areas, while a majority of ranchers recognize that variable climate and water loss jeopardizes their lifestyle, they seldom use meteorological information in planning or modify their water consumption. Climate vulnerability also includes potential for serious environmental health issues due to the presence of heavy metals and organic contaminants in the San Pedro.

Results of this survey have been published in the peer-reviewed journal, *Climatic Change* (Vol. 85, Nos. 3-4, Dec. 2007; online version appeared in Sept. 2007), as “Climate, water management, and policy in the San Pedro basin: results of a survey of Mexican stakeholders near the U.S.-Mexico border (Browning-Aiken, Morehouse, Davis, Wilder, Varady, Goodrich, Carter, Moreno, and McGovern 2007).

2. Setting the stage for cooperation. Climate workshop in Hermosillo, Sonora.

The Udall Center and the Institute for the Study of Planet Earth (ISPE) convened a special climate workshop on 26-27 April 2004; the purpose of the meeting was two-fold:

- To explore the idea of a regional climate center, perhaps based in Hermosillo, a discussion initiated among Mexican and U.S. climatologists at a meeting in La Paz the previous year; and
- To meet with Mexican climatologists to determine their interest in participating or otherwise contributing to San Pedro Basin climate workshop(s), which the Udall Center and ISPE plan to hold as part of a NOAA grant. The workshop(s) is/are expected to help specific stakeholders, such as water managers, city planners, and ranchers or ejidatarios (residents of communal rural settlements), understand climate better so they can consider climate variability in their decisionmaking.

Investigator Melanie Lenart explained the functions of CLIMAS, a NOAA-funded project administered through the University of Arizona’s Institute for the Study of Planet Earth. There was interest in how CLIMAS adds value to climate information in its products and publications and its work with stakeholders. CLIMAS’ initiative on providing a seasonal wildfire forecast for the Southwest attracted particular interest,

and participants were disappointed that the forecast does not cross the U.S. border with Mexico. Similarly, the monsoon was identified as a phenomenon that should be studied on both sides of the border. Tereza Cavazos and Henry Diaz were involved in the North American Monsoon Experiment (NAME) being carried out in Mexico that summer.

The general sentiment seemed to be that CLIMAS would be a good role model down the road, but that infrastructure for a regional climate center would need to be in place before the group meeting in Hermosillo would be ready to move forward on working with stakeholders. An attempt to discover interest from a potential stakeholder, CONAGUA, faltered when its representatives indicated they did not know what they needed.

Collecting and organizing data would be one of the first steps undertaken by the center, participants agreed. Benjamin Valdes of INIFAP suggested that perhaps CLIMAS and SAHRA could indicate their support for a regional climate center with a letter of cooperation. Melanie Lenart concurred. In Sonora, there are 145 stations, of which 40 to 50 report daily data by radio and other media; 16 hydrological stations, although not all of them are working; and large-scale data collected annually.

Julio Cesar of IMADES advocated a Sonoran-wide climate monitoring system. He noted that there's a big difference in climate between northern and southern Sonora. The region needs: real-time data that is accurate; warning for extreme events; and resource protection, he said. A system is in place, that uses data transferred by satellite from automatic weather stations, and is used by farmers, ranchers, the government, NGOs, the public and students, among other stakeholders. He discussed setting up a larger system (with each station costing about \$12,000). It would cost about \$1 million to set up 70 stations, and then about \$140,000 a year to maintain them.

Jose Grageda of INIFAP gave a presentation on the state network to modernize Sonoran agricultural climate products. CONAGUA is a source of information, but the infrastructure is inadequate and difficult to access. He suggested a system that would cost \$6.6 million pesos a year (about half a million dollars) to produce this information. Jaime Garatuza of ITSON suggested that the networking aspirations should be considered separately from the regional climate center idea.

Some representatives from the agricultural sector indicated ranchers needed climate forecasts about a month in advance, whereas farmers needed perhaps six months warning of a dry season so they could find other work. Diaz explained that a six-month categorical forecast would not be feasible, and that the probabilistic approach to forecasts would be more likely. The regional center could be a conduit for making such forecast useful to the user. Lenart was asked to consider how CLIMAS might be willing to be involved in the regional climate center.

3. Building support for and including societal impacts in the development of a prototype "Climate Outlook" package for the U.S.-Mexico border area

a. Background

Beginning in mid-2005, the project research team began developing a draft prototype "climate outlook" package for the Mexico border area. This prototype is based on a monthly outlook for Arizona and New Mexico produced by the NOAA/OGP-funded Climate Assessment for the Southwest (CLIMAS) Project (www.ispe.arizona.edu/climas/forecasts/swoutlook.html); and the analogous Intermountain West Climate Summary of the Western Water Assessment (www.colorado.edu/products/forecasts_and_outlooks/intermountain_west_climate_summary/)

The value of a single source for climate information, such as the Southwest Climate Outlook, has been validated through research conducted by CLIMAS and other RISAs. Participants in the extended survey of the Arizona-New Mexico climate outlook package were found to place high value on region-specific commentary included with the climate products, and to prefer "one-stop shopping" for information produced by different agencies. A draft table of contents for the prototype border-area package is below:

Table of Contents, prototype “Climate Outlook” package for the US-Mexico border area

Recent conditions

\$ Temperature (monthly and seasonal)

Sources: CNA (Mexico actual temp.), IRI/Columbia (U.S.-Mex. border departures fr. avg. temp)

\$ Precipitation (monthly and seasonal)

Sources: CNA (Mexico actual precip.), IRI/Columbia (U.S.-Mex. border departures fr. avg. precip.)

\$ Drought Status (monthly)

Source: NCDC North American Drought Monitor

\$ Reservoirs and Streamflow

Source: Avail. on fishing conditions Web sites & IBWC site; pending CNA approval for use of official data

Forecasts/outlooks

\$ Temperature (seasonal)

Source: IRI/Columbia (seasonal for North America)

\$ Precipitation

Sources: CNA (monthly); IRI/Columbia (seasonal for North America)

\$ El Niño

Source: IRI/Columbia

Forecast Verification (seasonal; contrast previous forecast products with recent conditions data)

\$ Temperature

Source: IRI/Columbia

\$ Precipitation

Source: IRI/Columbia

Sample contents of the prototype are included in the 2005 and 2006 annual reports.

The proposed climate summary brings together in one place information available from a variety of sources in the U.S. and Mexico on drought status, surface water status, recent temperature, and forecasts for the coming month and season. With further development, we anticipate that the package will also include value-added, region-specific information contributed by U.S. and Mexican scientists.

Since August 2005, the research team has worked to enlist Mexican collaboration by convening several important meetings and participating in key events—all but one in Mexico.

b. Key Events

- **Planning meeting, Cuernavaca** (Aug. 2005)

The first meeting in this series was held in Cuernavaca, at IMTA headquarters, in August 2005, and was attended by Michel Rosengaus, the director of Mexico's National Meteorological Service (SMN); Javier Aparicio, the director of IMTA's hydrological applications program and René Lobato, its director of climatological processes, and two of Mexico's leading climatologists (Carlos Gay and Cecilia Conde).

- **Workshop, Hermosillo** (Jan. 2006)

Andrea Ray of NOAA in Boulder, and Gregg Garfin and Robert Varady of the UA organized a one-day program, “Mexico-U.S. Workshop to Develop a Climate Outlook Product and Stakeholder Decision Support for Northern Mexico,” in Hermosillo, Sonora, on 10 January 2006. Its purpose was to discuss the joint development of a climate information product for the U.S.-Mexico Border Region.

The meeting was attended by Willebaldo Alatríste Candiani (Protección Civil Sonora), Carlos Arias (Protección Civil Sonora), Miguel Cortez Vázquez (SMN – Servicio Meteorológico Nacional), Jaime Garatuza Payán (ITSON – Instituto Tecnológico de Sonora), Gregg Garfin (CLIMAS – Climate Assessment for the Southwest, University of Arizona), David Gochis (NCAR – National Center for Atmosphere Research), Arturo López Ibarra (CONAGUA/CNA – Comisión Nacional del Agua), Martín Montero Martínez (IMTA – Instituto Mexicano de Tecnología del Agua), Andrea Ray (Western Water Assessment, NOAA Environmental Science Research Laboratory), Robert Varady (Udall Center for Studies in Public Policy, University of Arizona), and Chris Watts (UNISON – University of Sonora).

The participants issued the following “Statement of Mutual Interest for Future Collaboration on a North American Monsoon Region Climate Outlook Product,” which is included in a report submitted by Gregg Garfin to NOAA on 28 February 2006:

There is a pressing need for climate information in the U.S.-Mexico border region that brings together information from Mexico and the U.S. from multiple agencies in both countries into a format usable and easily accessible by decision-makers. In order to address this need, a binational work group of 11 researchers and officials* met in Hermosillo, Sonora, on January 10, 2006, to discuss the potential of developing a climate outlook product for a portion of the U.S.-Mexico border region. Based upon a model of two such products in use by the Climate Assessment for the Southwest Project (CLIMAS, University of Arizona) and the Western Water Assessment (WWA, University of Colorado and NOAA), the group strongly agreed to continue exploring the preparation of a similar tool for use by Mexican and U.S. decision-makers and stakeholders in the area that straddles the two nations.

Participants discussed the geographic domain, based on ecological and hydroclimatological boundaries. They identified potential research partners and user institutions, listed sources for and types of data and information to be included, and resolved to continue the development process via a Web site for communication. A crucial challenge is to identify and apply for support. In the interim, the participants have agreed to find ways to continue their involvement.

Finally, the work group decided to expand and to meet again at the Monsoon Region Applications Science Workshop in Sonora, Mexico, in May, 2006.

- **Fourth World Water Forum, Mexico City (Mar. 2006)**

A third planning meeting was convened in conjunction with the Fourth World Water Forum, held in Mexico City between March 16 and March 23, 2006. Again, important officials of SMN (Valentina Davydova, the deputy director, and Cortez); IMTA (Aparicio, Lobato, and Montero); and three University of Arizona researchers participated (Varady, Browning-Aiken, and Katharine Jacobs). Discussions included ideas for securing funding to begin producing the outlook product. Clearly, by this time, the Mexican officials were keen on the idea and ready to begin a partnership. This meeting, too, was supported by funds from NOAA Headquarters.

- **Binational Workshop on Monsoon Region Climate Applications, Guaymas (May 06)**

The fourth session was the Guaymas workshop, held between May 8 and May 11, 2006. This event was attended by about 60 persons, with more than half from Mexico. All of the individuals named above were there, as well as many other researchers, officials, and stakeholders. The two major additions were Ing. Arturo Herrera, the commissioner of the Mexican CILA (the international border water commission) and his counterpart, Carlos Marin, the acting commissioner of the IBWC, the U.S. section of the commission. Both of the commissioners seemed willing to lend support to the climate outlook idea as well as to a host of other climate/water-related undertakings. The conference, whose Web site is at www.ispe.arizona.edu/climas/conferences/monsoon2006/, ended with the adoption the following action items:

- A community of scientists, managers, and policymakers exists with interests in applications of climate research in the monsoon region. These include climate and social scientists, and resource managers and policymakers from local, state, and federal agencies in the U.S. and Mexico.
 - There is an interest in regular meetings such as this every 18 months or 2 years.
 - There is a need for a means for communication among this group, via an email listserv and a Web page.
 - We should sponsor special sessions at appropriate professional society meetings.

- There is interest in and a need for a binational Climate information product in English and Spanish, and an agreement that such a product would help develop scientific literacy about climate information in the region.
- There is a need for a regional climate center for northwest Mexico and the border region, which would serve as a center for information not only for this region in Mexico, but also to develop “borderless” products for the many users with transborder interests.
 - The SMN supports the idea of a regional climate center, but agreements need to be worked out on authorities.
- There is a need for “Regional integrated science and assessment” for this region, similar to the model developed in the U.S.
- Stakeholders for climate information in the monsoon region are diverse. Sectors include:
 - Drought and natural hazards management, including flooding, wildfires
 - Water management at several spatial and management scales, including urban water, irrigation, reservoir management, dryland farming and ranching, and management of water under the IWBC/CILA
 - Management of protected areas and ecological diversity and sustainability
 - Coastal management
 - Public health
 - Fisheries of the Gulf of California
- There is a need for funding that is stable for activities like a regional climate center, a binational climate information product, and regional assessment. The participants recognize that funding is likely to come from multiple sources.
- There is a need for training opportunities for people, e.g. for more interdisciplinary understanding, for people who are integrators, and for specific tools for use in resource management, e.g., GIS.

The Guaymas conference was funded by a grant from NOAA Headquarters to the Physical Sciences Division of NOAA’s Earth Systems Research Laboratory in Boulder. The statement goes on to say that once the concept and prototype has been fully accepted and endorsed by Mexican scientists, managers, and policymakers for further development, we hope to conduct a user survey of the prototype by distributing copies of the outlook to selected border-area stakeholders for their evaluation and suggestions for revision and improvement. The ultimate goal is for production and dissemination of the outlook to be undertaken and implemented by the appropriate Mexican stakeholder entity.

In spite of the progress made over the past nine months, the participants cautioned that it is important to note that further work on the border-area outlook is proceeding with extreme caution due to the political issues discussed above and the imperative need to secure approval from Mexican entities such as CONAGUA and SMN.

The prototype border-area package brings together in one place information available from a variety of sources in the U.S. and Mexico on drought status, surface water status, recent temperature, and forecasts for the coming month and season. With further development, we anticipate that the package will also include value-added, region-specific information contributed by U.S. and Mexican scientists. Once the concept and prototype has been accepted and endorsed by Mexican scientists, managers, and policymakers for further development, we hope to conduct a user survey of the prototype by distributing copies of the outlook to selected border-area.

A summary of the outcomes of the Guaymas workshop, including progress toward the implementation of a border climate summary product, was published in June 2007 in the *Bulletin of the American Meteorological Society*, as “Monsoon region climate applications: Integrating climate science with regional planning and policy” (Ray, et al. 2007).

- **CRCES workshop on decadal climate variability, Kona (Apr. 07)**

The Center for Research on the Changing Earth System (CRCES), with funding support from NOAA and the U.S. Army Corps of Engineers, organized a workshop on the subject of societal adaptation to decadal climate variability. While the primary focus was on the United States, the workshop also looked at the U.S.-Mexico border region and PI Robert Varady was accordingly a member of the workshop’s organizing

committee. In a coauthored paper, Varady presented a case study, based on work by project investigators, of societal impacts in the border region (Varady, Wilder, Garfin, and Morehouse 2007). A summary of the workshop was published in October 2007 in *Eos* as "Societal adaptation to decadal climate variability in the United States" (Rosenberg, et al. 2007).

- **AGU Joint Assembly, Acapulco (May 07)**

The Spring 2007 AGU Joint Assembly was held in Acapulco, Mexico, and so offered an excellent opportunity for project researchers to present some of their findings to interested colleagues from across North America. Accordingly, abstracts were submitted and accepted for four different papers.

The first paper, "Establishing an ongoing binational U.S.-Mexico border climate diagnostic summary: Developing a prototype and navigating the institutional landscape" (Garfin, Varady, and Ray 2007), provided up-to-date information on the progress of the binational climate summary described in the present section, Part III.3. The second, titled "Institutions and societal impacts of climate in the Lower Colorado and San Pedro Basins of the U.S.-Mexico Border region" (Varady, Garfin, Morehouse, and Wilder 2007), was an adaptation of the presentation made at the CRCES workshop. The third was "New water management institutions in Mexico's 'New Culture of Water': Emerging opportunities and challenges for effective use of climate knowledge and climate science" (Wilder, Varady, N. Pineda Pablos, A. Browning-Aiken, R. Díaz Caravantes, G. Garfin 2007). Finally, a fourth paper summarized binational water-and-climate work in the Upper San Pedro basin (Goodrich, D. H. Richter, R. Varady, A. Browning-Aiken, and J. Shuttleworth. 2007).

c. Maintaining momentum: Continuing activities

- **IAI award for new project (July 07)**

In spring 2007, the project team, along with additional colleagues in Mexico and the U.S. (most notably at IMTA and UNAM in Mexico and at NOAA/Boulder and NCAR in the U.S.) submitted a proposal to the Inter-American Institute for Global Change Research. The proposal, entitled, "Information Flows and Policy: Use of Climate Diagnostics and Cyclone Prediction for Adaptive Water-Resources Management Under Climatic Uncertainty in Western North America," was funded at a level of about \$140,000 in mid-2007 and is just getting under way in fall 2007.

With assistance from SMN in Mexico, this effort will provide resources to begin to implement the border climate summary the project team has been promoting since 2005.

- **Anticipated meeting at CICESE in early 2008 (Ensenada)**

CICESE and NOAA scientist Andrea Ray have been planning for a workshop intended to follow on some of the discussions at the 2006 Guaymas workshop and the 2007 AGU Joint Assembly. Antonion Badan and María Tereza Cavazos of CICESE and Ray have drafted an agenda for a workshop to be called, "The State of the Drought on the Western U.S.-Mexico Border Region," to be held at CICESE's headquarters in Ensenada, Baja California, in early 2008.

Motivated by the current drought and lack of skill of seasonal forecasts, the objective of the event will be to discuss recent climatic behavior to examine causes of the current drought and predictability associated to seasonal climate forecast skills.

The topics for discussion will include: Drought; how to improve regional seasonal climate forecasts skill in Northwest Mexico; products and applications—including notably, seasonal climate outlooks for agriculture; fisheries; hydrology users; and institutional collaborations.

The members of the project team will participate fully in this upcoming workshop to continue the momentum achieved over the past four years.

4. Promoting binational use of DSS tools: Coupling hydrologic modeling with policymaking to assess the impacts of climate variability and change

a. Background

As a consequence of a series of meetings with academic colleagues in Sonora, research team members came to appreciate the desire to develop a set of decision-support systems (DSS) tools that would be of mutual benefit. Beginning in the first project year, work was under way on such a tool being developed by UA engineering professor Kevin Lansey, under the auspices of the SAHRA project (see June 2004 and July 2005 progress reports).

b. Research team

Anne Browning-Aiken, Aleix Serrat Capdevila, Alison Williams, and Kevin Lansey

c. Objective

Allocating water resources within a basin is a complex problem. Population growth, industrial development, and agriculture have brought major societies to the edge of water resources availability. Furthermore, human development is affecting global climate patterns (climate change). Assessing the impacts of climate variability and change in water resources and planning for future management strategies requires holistic and interdisciplinary approaches, merging physical sciences and policy making. While climatic and hydrological models serve as physical bases for estimating hydrologic futures, decision support systems provide a common arena for stakeholder involvement and consensual science-based decision and policy making. Also, agent-based models can recreate stakeholders in a basin and assess potential policies by evaluating emergent patterns.

The overall goal of this research is to provide a multidisciplinary approach and a set of tools to enable adaptive capacity in the management of regional watersheds in the face of large variability and potential climate change. For this, it is necessary to bridge physical hydrology knowledge with policy and complex systems theory for the socio-ecological management aspect.

The first objective is to quantify the impact of different climate change scenarios on the water resources of different basins throughout Arizona, namely the San Pedro River, the Salt River, and the Verde River basins. All of these watersheds support important human developments and environmental areas, and are characteristic of different hydrologic regimes within the state. Work is under way in the San Pedro basin, where changes in temperature and precipitation—thus in groundwater recharge—are being evaluated with hydrological models to assess potential changes in the basin's water budget.³

The second objective is to present a representative range of potential climate-change impacts in a manner understandable to stakeholders and decisionmakers. In the case of the transnational San Pedro, the objective is to include these climate-change scenarios and their hydrological impact in the Decision Support System model (DSS) that is being developed for the Upper San Pedro Partnership (USPP).

Assessing the climate variability and change impacts on the water resources of the Verde, the Salt, and the San Pedro—three regional basins with different hydrologic regimes—will provide a powerful insight on climate variability and change effects and the degree of vulnerability of Arizona's watersheds to such changes. The inclusion of these potential impacts on the hydrology in the San Pedro basin's DSS model will allow the USP Partnership to evaluate strategies to meet safe yield and cope with a changing water balance under future scenarios. For all three basins, the ability of adequate policies to face global change impacts will help provide sustainable solutions for the short term and build adaptive capacity to accommodate change, should it ever come.

d. Progress

An initial binational meeting took place in July 2005; that meeting was attended by José María Martínez (Universidad de Sonora), José Luís Moreno (Colegio de Sonora), Nicolás Pineda (Colegio de Sonora), Manuel de Jesús Sortillón (Universidad de Sonora), Pablo Wong (Centro de Investigación en Alimentación y Desarrollo), Anne Browning-Aiken (Udall Center), Aleix Serrat (Udall Center and SAHRA).

³ The U.S. Congress mandate in the San Pedro Basin requires safe yield (withdrawals = recharge).

The subject of the session was “Explorando Modelos de Ayuda a la Decisión para la Gestión del Agua en Arizona/Sonora: El ejemplo del Río San Pedro” (“Exploring Decision Support Models for Water Management in Arizona-Sonora: The Example of the San Pedro River”), t El Colegio de Sonora, in Hermosillo (organized by Anne Browning-Aiken and Aleix Serrat Capdevila). The meeting was extremely interactive and positive and evinced serious interest on the part of the Mexican academics. Among future plans is another meeting in the fall to discuss the inclusion of climate components in the proposed DSS model.

Another presentation and meeting were held a month later in the Universidad de Sonora to discuss similar collaboration possibilities to develop Decision Support System Models collaboratively. Professors from the Departamento de Investigaciones Científico Técnicas de la Universidad de Sonora (DICTUS) constituted the audience: Dr Alejandro Castellanos (director), his team, and other faculty (approximately 12 attendants).

The main topics touched during the discussions that ensued from these meetings can be grouped in two main axis: (1) Model understanding, techniques, level of accuracy, variables, data sources, model uncertainty, application of results; and (2) Reflecting from the regional setting: Strong political character of water management in Sonora and its consequences on efforts towards integrated participative management. A proposal was written to start a collaborative project with DICTUS: “Integrative Water Resources Management in Transboundary Basins. A collaborative proposal for the development of the Upper San Pedro Basin Decision Support System by the Udall Center (University of Arizona) and DICTUS (Universidad de Sonora).”

Despite initial enthusiasm, and the fact that efforts were intensely pursued to start a concrete academic collaboration project, DICTUS stated that due to many reasons, this was not a current priority for their center at this point.

Since that decision, over the past year (2006-07), on the Mexican side of the border, both the Colegio de Sonora (COLSON) and the University of Sonora (UNISON) have expressed interest in adapting this DSS model—with its new inclusion of climate information—for application in northern Sonora. Through various presentations, seminars, workshops, and other programs, researchers at the Udall Center and SAHRA have introduced Mexican students and water managers to the model and given them the opportunity to test it by exploring alternative management strategies.

Besides fruitful and ongoing collaboration with COLSON, a very strong institutional contact has developed with the CONAGUA authorities for the Sonoran Region. We think this is a direct implication of our involvement in the above mentioned capacity building and educational programs. A delegation from the Hermosillo CONAGUA office visited the University of Arizona in April 2007, where they attended organized presentations regarding Decision Support Systems (by Kevin Lansey) and Climate Variability and Change (by Aleix Serrat-Capdevila) and further discussion were had regarding transboundary stakeholder-relevant collaboration.

At present, a collaborative proposal to address water resources management challenges in the Sonoran region developing DSS tools has been written and electronically sent back and forth across the border to CONAGUA-Hermosillo for new ideas and modifications. The stated goals of the proposal are: (1) Identify, water management domains where the development and use of computational tools such as decision support systems, can be useful for water managers; and (2) Once these domains are identified, establish the foundations for the joint development of decision support systems to solve concrete problems in regards to coping with climate variability and change.

The formal invitation from CONAGUA to assist in the meeting to create a *Comisión de Cuenca* in the Mexican part of the San Pedro Basin is in itself a demonstration of the trust and strong institutional links that have developed as product of our collaborative efforts. Anne Browning-Aiken, Chris Scott and Aleix Serrat-Capdevila attended this unprecedented meeting where the *Comisión de Cuenca* was created and our collaborative efforts pushing that way were publicly recognized. Dr Roberto Salmon, Director Regional del Organismo de Cuenca, acknowledges the San Pedro Basin as a *Proyecto Estelar*, and declares the intention to work towards a bi-national commission for the management of the basin’s water resources.

e. Activities

- July 2005. Organized and participated in a session at El Colegio de Sonora, Hermosillo: "Explorando Modelos de Ayuda a la Decisión para la Gestión del Agua en Arizona/Sonora: El ejemplo del Río San Pedro" ("Exploring Decision Support Models for Water Management in Arizona-Sonora: The Example of the San Pedro River"). Attendees included José Maria Martínez (Universidad de Sonora), José Luís Moreno (Colegio de Sonora), Nicolás Pineda (Colegio de Sonora), Manuel de Jesús Sortillón (Universidad de Sonora), Pablo Wong (Centro de Investigación en Alimentación y Desarrollo).
- Nov. 2005. Cochise College DSS teaching demonstration for Technical Advisory committee of Upper San Pedro Partnership.
- Nov. 2006. Lecture in the setting of the Program for Consejos de Cuenca (Basins Water Councils) organized by the Comisión Nacional Del Agua (CNA/CONAGUA) and El Colegio de Sonora (COLSON). The lecture presented capabilities of dynamic modeling to support decisionmaking and presented case studies of previous Decision Support System Projects. The audience was mid-level officials from the Comisión Nacional del Agua from the Sonoran region.
- Jan. 2006. Colegio de Sonora teaching demonstration workshop and lab for use of DSS model with climate components, seminar, "Especialidad en Gestión Integrada de Cuencas Hidrográficas" ("Specialization in Integrated Management of Hydrological Basins").
- Mar. 2007. Gregg Garfin evaluated and met to advise the core research group working with Kevin Lansey, in order to orient them to the DSS website and product usability evaluation philosophies and methods.
- Apr. 2007. Visit to the University of Arizona of a CONAGUA delegation from the Hermosillo offices.
- 24 Oct. 2007. The *Comisión de Cuenca del Río San Pedro* is created with the attendance of three members of the Udall Center.

5. Raising awareness by educating the young. Development of a pilot K-12 curriculum on climate and drought for the Arizona-Sonora region

a. Background

When the research team leadership met in September 2004 to consider ways to adapt to the changed political circumstances in Mexico, all agreed that we needed to strongly continue to try to bridge the communications gap. One of the best ways to achieve this, we felt, was to concentrate on environmental education for the population at large. Such an approach would take advantage of vigorous efforts already underway in this area and to modify these by introducing curricular materials on climate variability and change.

b. Research team

Anne Browning-Aiken (Udall Center), Margaret Wilder (Center for Latin American Studies; CLAS), Floyd Gray (UA Dept. of Geosciences), Yajaira Gray (Arizona-Sonora Desert Museum), Denisse Fisher de León (Udall Center), Lisa Shipek (CLAS), Julie Kentnor (CLAS), Gigi Owen (CLAS)

At the Udall Center, co-PI Anne Browning-Aiken has developed a program called ECOSTART, which is now entering its third phase (ECOSTART III). With seed funding from EPA, SAHRA, the Morris K. Udall Foundation, and a number of local community associations, Browning-Aiken and her ECOSTART team have been working with primary and secondary school teachers in Arizona and Sonora to introduce environmental topics into existing school curricula. Until recently, most of the subject matter pertained to water resources, especially to issues involving the San Pedro. Now, under the impetus of the present project, with the assistance and cooperation of then-CLIMAS manager and project co-PI Gregg Garfin, and in collaboration with co-PI Margaret Wilder, ECOSTART has been introducing new items on climate, drought, flooding, and forecasting. The aim is to raise awareness among young persons, who will eventually be stakeholders.

Margaret Wilder worked with two research assistants on specific climate and drought curricula for teachers and students in the Arizona-Sonora border region.

As part of the project's curriculum-development activity, the research team prepared and has been distributing a CD containing a 4th grade unit "Drought Beyond Borders" and an 8th grade unit "Climate Change Beyond Borders," both in Spanish and English.

The curriculum also is available on the Udall Center's Web site at:

<http://www.udallcenter.arizona.edu/publications/santacruzwatershed/index.html>. Separate materials also have been prepared bilingually for the transboundary San Pedro River basin.

These materials have been peer-reviewed and field-tested in the Santa Cruz basin and are currently being peer-reviewed by members of the College of Education, the Extension Division, CLIMAS, and the GLOBE Education Program at the University of Arizona. Educators will review and field test the CD with the San Pedro adaptations in Cochise County. Revisions in response to the reviews will require a new modest source of funding.

c. Research Design

Based on our analysis of information gathered during this phase, we developed the following target areas of focus:

- Focus on 4th and 6th grade curricula as most appropriate points-of-entry where this curriculum could be offered.
- Due to the already full curriculum in TUSD with little space to spare for introducing new material, develop the pilot curriculum as short (1-3 days) lesson plans, rather than a full-blown curriculum.
- There is no need to develop a curriculum on water, as "Project WET" already has an excellent curriculum for K-12 level on water.
- Based on interactions with teachers via the Center for Latin American Studies (CLAS), K-12 teacher email listserv and follow up interactions, as well as feedback from a visiting Sonoran teachers' group, we believe there is sufficient teacher interest in the curriculum project to warrant moving forward.

d. Research Activities

- Meetings with approximately 20 curriculum experts (at UA and TUSD), drought and climate scientists, Tucson and Sonoran teachers, and professional associations (e.g., Arizona Geographic Alliance) to assess the current state of K-12 curricula in TUSD and to identify significant gaps.
- Gather materials for archive on existing K-12 science curricula and requirements.
- Additional efforts are listed in the 2005 and 2006 annual reports. Throughout this activity, project researchers have established relationships with teachers in Sonora and Arizona and, especially within environmental education programs, to begin disseminating it further. CDs of the curriculum have been widely distributed to educators in the region, most recently at the 2007 workshop of the Arizona Association of Environmental Education.
- Demonstration and use of a Decision-Support System model at the Colegio de Sonora and the University of Sonora (as described in a preceding section) have been effective ways to educate specialists who will become water managers and technicians.

6. Use of climate and water information in Mexico's northern border region

a. Background

As described in section II above, at the conclusion of the project's first year, it became necessary to redefine the scope of work. Researchers had assessed the effects of political obstacles in Mexico, and decided to examine in depth several key aspects of the water-and-climate context in northern Mexico. Accordingly, the research team set out to study the following aspects of that context: (1) the nature of collaborative knowledge production for improved water management, factoring in climatic information (2) the impacts on water-climate management and climate science of Mexico's recent decentralization; (3) the character of challenges to implementing integrated transboundary water planning, again including

climatic information and climate science; and (4) obtaining a realistic measure of the institutional dimensions of ecosystem sustainability, with special reference to water and climate.

b. Research team

Nicolás Pineda Pablos, Margaret Wilder, Anne Browning-Aiken

c. Goals

Interview Sonora municipal, state, and federal water agency officials concerning changes in the Mexican water laws and challenges to implementing water policy in the Mexican portion of the San Pedro basin—including challenges related to paucity of and extent of use of climate information. The research team also reviewed documents about the water service in Cananea, mainly in government and legal documents. This included inquiries at the Registro Público de Derechos de Agua, a review of the CONAGUA/CNA annual report on water utilities and the benchmarks published by the Comisión Estatal de Agua Potable y Alcantarillado de Sonora.

d. Research Activities

Project researchers conducted interviews with a broadly representative group of managers and stakeholders in Sonora.

- Among those interviewed regarding the system of benchmarking for water utilities in Sonora and the process of decentralization and transfer of water from the state administration into the municipalities were: Ing. Sergio Pablos and Ing. Francisco Salinas of COAPAES,.
- In regard to the situation of the Consejos de Cuenca (river basin councils) and the organization of the well-water users in the Costa de Hermosillo, researchers interviewed Dr. Roberto Salmón Castelo, Gerente Regional de la Comisión Nacional del Agua, regarding the situation of the Río San Pedro and other water topics in Sonora, and José María Martínez.
- The process of modernization and decentralization of water utilities was explored via interviews with Ing. Renato Ulloa, Director de la Comisión de Agua Potable y Alcantarillado del Estado de Sonora (Coapaes), and with José Luis Corrales, director del Organismo Operador Municipal de Agua Potable y Alcantarillado (Oomapa) de Naco, Sonora. Additionally, interviews in Cananea with: Sr. Jesús Ahumada (Chuchi) director del Patronato de Agua Potable (PAC) de Cananea, Ing. Rafael Valdez, director comercial del PAC, Ing. José Fernando Rodríguez, Director de Capacitación de la Empresa Minera de Cananea, Francisco García Gamez, Presidente Municipal, Ing. Tirado Verdugo, Director de Obras Públicas del Municipio de Cananea, Sr. José Rosario Trique, residente de Cananea y trabajador de la mina, Sra. Isabel Rojas y Mercedes Salazar, bibliotecarias y ciudadanas de Cananea.

e. Results

All four of the research questions described in the background section above were investigated in the course of the project's lifetime. Among the achievements were several major papers:

- "Water Management in Mexico's 'New Culture of Water.' Emerging Opportunities and Challenges for Climate Science and Climate Knowledge" (Wilder, Varady, Pineda Pablos, Browning-Aiken, Diaz Caravantes, and Garfin, in submission), and "Equity and water in Mexico's changing institutional landscape" (Wilder, forthcoming 2006)—both on the subject of Mexican water reform and its impacts.
- "Equilibrio de bajo nivel y manejo urbano del agua en Cananea, Sonora" (Pineda Pablos, Browning-Aiken, and Wilder. 2007), and "Challenges to implementing Mexican water policy: a political ecology perspective on water resource collaboration, institutional bureaucracy, and local participation" (Browning-Aiken and Pineda. 2005)—on the topic of binational transboundary collaboration on water and climate management.
- "Science and socio-ecological sustainability: Examples from the Arizona-Sonora border" on institutional dimensions of ecosystem sustainability (Morehouse, Ferguson, Owen, Browning-Aiken, Wong-Gonzales, Pineda, and Varady, in press).

B. Findings

1. Interim

a. From 2004 annual report

One of the challenges of the San Pedro aspect of the project involves the difficulty in accessing information on climate variability in real time. There is no web-based data storage system to which a user can turn for information on how local temperature and precipitation compare to previous years, for instance. In most places, climate monitoring did not begin until the 1960s, and data collection was not always consistent. Some records begin in the mid-1980s, and there are many gaps in climate records. CONAGUA reportedly has some of this data, but charges a fee for its use. The availability of information is such that collecting and organizing data was identified as a necessary first step of a proposed regional climate center by the dozen or so climatologists from Mexico or with expertise on Mexico who attended the April 26-27 meeting in Hermosillo. The regional climate center is proposed for establishment at the University of Sonora in Hermosillo, Mexico. Participants in the planning workshop who attended a presentation by CLIMAS postdoctoral researcher Melanie Lenart responded with the general sentiment that producing value-added climate products for stakeholders was probably beyond the scope of the proposed regional climate center in its early stages. Given that this is seen as a challenge by Mexican climatologists, it seems unlikely that a U.S.-based project will be able to develop such stakeholder tools, as had been initially proposed in this grant.

However, it does seem possible to use workshops to provide stakeholders with a basic background on the climatic influences that affect the San Pedro watershed, such as the monsoon and the El Niño Southern Oscillation (ENSO). The Nature Conservancy is planning to hold a workshop in Spanish for Sonoran ranchers on the Mexican side of the border, and TNC organizer Peter Warren has been supportive of a suggestion that someone from this grant give a presentation on climate variability in the region as part of the one-day workshop scheduled for September. In addition, the North American Monsoon Experiment (NAME) provides some opportunity for stakeholder education that could be facilitated by recipients of this grant. Further, some of the Mexican climatologists who attended the Hermosillo meeting indicated they would be interested in collaborating in the National Seasonal Assessment Workshops, led partly by CLIMAS, to identify potential western fire risk for the upcoming season based in part on climate forecasts. Participants in this grant may be able to serve as a bridge to facilitate the future involvement of Mexican stakeholders in the NSAW initiative.

In the meantime, the grant is providing funding for a graduate student researcher to collect data on climate variability as it applies to this region. Information is being compiled about what data is available and what peer-reviewed and other papers are relevant for potential stakeholder workshops. It is hoped that the data will be compiled into a Spanish-language information booklet that can eventually be distributed to interested stakeholders in the region. Also, co-PI Tereza Cavazos has compiled a list of web-based weather and climate information, many of them produced by U.S.-based agencies, that she makes available from her web page at the following address:

<http://oceanografia.cicese.mx/~tcavazos/weather.html> . Some of these links could be provided to stakeholders as relevant to their concerns.

When Morehouse and Browning-Aiken met with the Upper San Pedro Partnership about becoming participants in an assessment of climate information tools in basin water management in the US portion, the Partnership stated it had sufficient access to climate information tools through its connection with the army base at Ft. Huachuca. However, as indicated above, climate data can be inserted into the DSS model by Lansey and Yalcin.

The greater challenge has been to get CONAGUA to cooperate with researchers and basin water managers in supporting the establishment of a Mexican water committee in the basin. Due to higher priority concerns elsewhere in the state, CONAGUA says it will provide support by the end of this year.

Many of the findings and results of the Mexican San Pedro Water and Climate Survey point strongly toward vulnerability associated with lack of basic water infrastructure, water quality concerns, and institutional issues than they do toward climatic vulnerability. However, given the high baseline level of water vulnerability, climatic variability and change have the potential to intensify the effects of already-

existing problems. The observations below provide insight into the multiplicity of challenges faced by Mexican stakeholders in the Upper San Pedro River Basin, and into how climate information might be successfully integrated into decision making at scales ranging from households to the entire upper basin.

- Observation #1 Water managers' and water users' access to resources, specifically finances and technology, and local management capacity play a critical role in determining water system vulnerability.
- Observation # 2: Urban and rural water users recognize that water service problems, particularly those associated with water quality, can impact regional health, but, not surprisingly, tend to associate these problems with water management rather than climate variability.
- Observation #3 Water users do not believe that lack of access to reliable information about climate and aquifer conditions contributes to the vulnerability of their water system or to access to reliable potable water service.
- Observation #4 Urban and rural water users do not currently modify their water consumption in response to climate variability or change.
- Observation #5 Water managers do modify their management strategies in response to climate variability or weather stresses.
- Observation #6 Few urban or rural households have water storage capacity to meet their water demands under drought conditions.

b. From 2005 annual report

At the time of this report, the project is 22 months into its 36-month lifespan. In the first interim annual report, we reviewed some of the findings of three Mexican San Pedro Water and Climate Survey. We found appreciable vulnerability associated with lack of water infrastructure, water-quality concerns, and institutional issues—but other than susceptibility to drought and flood, little evidence for vulnerability to climate variability or change. It was clear, however, that the socioeconomic weaknesses tend to exacerbate existing vulnerability to climatic events. In addition, the survey revealed a number of insights into the most immediate concerns of and coping strategies employed by water users, managers, and decisionmakers. The observations below provide insight into the multiplicity of challenges faced by Mexican stakeholders in the Upper San Pedro River Basin, and into how climate information might be successfully integrated into decision making at scales ranging from households to the entire upper basin.

The project team has expended considerable effort solidifying relationships with stakeholders and academics in the region. We have believed from the start that trust can only be established via repeated personal contacts. In keeping with this notion, through numerous trips to the basin, a major effort has been expended on scientific collaboration through participation in regular project meetings and planning activities. Over the past year, much of this effort has been directed toward identifying the best strategies for achieving open communications with and trust of key Mexican constituencies. Both of these factors are essential to moving forward with regard to the central aim of the project, which is to improve the availability of useful, usable, and relevant climate information for people living on both sides of the border in the Upper San Pedro River Basin.

In spite of the issues confounding and complicating the team's work, the contacts we have nurtured have paid off by facilitating access to people, institutions, and information. And as we reported on page 4, due in part to persistence and largely the natural course of events, the political tensions that characterized much of the past year appear to be easing. This has allowed us to strengthen our workings with counterpart scientists and to discuss ways to develop and implement better climate diagnostic products such as the prototype "Outlook" instrument described on pages 8 to 12. Other preliminary findings drawn from this project and closely related undertakings are shown in the lists of publications and presentations that appear just below. Still more research and writing is underway and by the project's end, we will have amassed a sizable collection of peer-reviewed papers and other research products, as well as concrete achievements in the information-bridging realm.

Still other preliminary findings:

- Such climate-related information as exists is almost exclusively short-term weather information, e.g., Weather Channel, NOAA/NASA, Federal Electric Commission, and other Web sites. Local

Protección Civil's responsibility is to deal with potential crises due to weather. This is the niche the Outlook instrument seeks to fill.

- In Arizona and even more so in Mexico, all water information is highly political, especially among agricultural districts or facilities maintained by the government.
- There has been little if any interest in long-term climate programs, although the recent sustained drought has generated some interest in fire prevention in Alamos and some interest in climate impacts among nongovernmental workers in Nogales community-based activists. At this time, it is deemed advisable not to convene holding stakeholder workshops because of a split between governmental water/climate programs and grassroots organizers—which stakeholders are you going to invite? If you invite one, you insult the other.
- Asymmetrical differences in economy and political structure between the two neighboring countries have long complicated binational natural-resources management. But social and political challenges to implementing water and environmental policy along the border may be further restricting opportunities for local or regional efforts to build the capacity of watershed councils for coordinated basin management. A series of binational meetings linking hydrological science and water-management technology and a Mexican community survey on water and climate demonstrates how science is subordinated to political will and examines how integrated binational and local water-resources planning is confounded by continuing centralized resource management in Mexico.
- The 2005 Water Management and Conservation Plan of the Upper San Pedro Partnership was published in March 2005 with the recognition that each town in the Arizona portion of the upper basin needs to include an account of their drought management efforts for their comprehensive general plan.
- The research team implemented a user evaluation of the Udall Center/SAHRA periodic publication, *San Pedro News & Comment (SPNC)*. In this survey, articles on climate variability and change were treated as a research tool and linked the SPNC's Web site was linked to SAHRA's much larger *Water Newswatch*.
- The team, led by co-PI Margaret Wilder and research assistant Lisa Shipek, has developed two educational curriculum units on climate change and variability for primary and secondary schools for use in the Mexico-US border communities. The group is working on a third curricular product that is expected to be ready by early fall 2005.
- With new funding from the Sierra Club, ECOSTART II is ready to begin integrating climate components into curricula for teachers in the San Pedro region.

c. From the 2006 annual report

At the time of this report, the project is 33 months into its originally-scheduled 36-month lifespan. Simultaneously with this submission and contingent on its approval we requested a 12-month no-cost extension in the life of the project.

In the first interim annual report, we reviewed some of the findings of three Mexican San Pedro Water and Climate Survey. We found appreciable vulnerability associated with lack of water infrastructure, water-quality concerns, and institutional issues—but other than susceptibility to drought and flood, little evidence for vulnerability to climate variability or change. It was clear, however, that the socioeconomic weaknesses tend to exacerbate existing vulnerability to climatic events. In addition, the survey revealed a number of insights into the most immediate concerns of and coping strategies employed by water users, managers, and decisionmakers. The observations below provide insight into the multiplicity of challenges faced by Mexican stakeholders in the Upper San Pedro River basin, and into how climate information might be successfully integrated into decision making at scales ranging from households to the entire upper basin.

As we have noted throughout this and previous reports, the project team has expended considerable effort solidifying relationships with stakeholders and academics in the region. We have believed from the start that trust can only be established via repeated personal contacts. In keeping with this notion, through numerous trips to the basin, a major effort has been expended on scientific collaboration through participation in regular project meetings and planning activities. During the 2004-05 project year, much of

this effort was directed toward identifying the best strategies for achieving open communications with and trust of key Mexican constituencies. Both of these factors were found essential to moving forward with regard to the central aim of the project, which is to improve the availability of useful, usable, and relevant climate information for people living on both sides of the border in the Upper San Pedro River basin.

During the past 11 months, the research team has expanded its reach and made a special effort to enlist the participation of broader networks of informants, stakeholders, and partners. In particular, we have forged strong relations with other institutions working on related projects—both in the U.S. and in Mexico. As identified on pages 6 and 7, this project is now working hand-in-hand with colleagues at NOAA/Boulder, NCAR, UNISON, ITSON, IMTA, and SMN. Within Mexico in particular, we have realized the importance of engaging and teaming up with officials and scholars working not only in the border region in Sonora, but others nearer to the capital city. Our attempts to implement a joint diagnostic climate outlook product and a DSS planning tool for the region have led to invaluable connections that we will continue to rely on in the coming year and beyond.

Much more than a year ago, we can assert that the contacts we have nurtured have paid off by facilitating access to people, institutions, and information. We have continued to strengthen our collaborations with counterpart scientists and to discuss ways to develop and implement better climate diagnostic products such as the prototype “Outlook” instrument described on pages 9 to 13. Other preliminary findings drawn from this project and closely related undertakings are shown in the expanding lists of publications and presentations that appear below. Still more research and writing is underway and by the project’s end, we will have amassed a sizable collection of peer-reviewed papers and other research products, as well as concrete achievements in the information-bridging realm.

Still other preliminary findings are:

- Such climate-related information as exists for Mexico is almost exclusively short-term weather information, e.g., Weather Channel, NOAA/NASA, Federal Electric Commission, and other Web sites. Local Protección Civil’s responsibility is to deal with potential crises due to weather. This is the niche the climate-outlook instrument seeks to fill.
- In Arizona and even more so in Mexico, all water information remains highly political, especially among agricultural districts or facilities maintained by the government.
- With a presidential election to take place in July 2006, Mexico’s future policies and actions in the water/climate domain are certain to be determined by the outcome, which is now uncertain.
- Until recently, there has been little if any interest in long-term climate programs, although the current sustained drought has palpably enhanced interest among officials, stakeholders, and citizens. As our meetings with Mexican colleagues have firmly shown, in spite of the tensions brought about by the caustic immigration debate, the political climate is now much more amenable to cross-border collaboration on water-and-climate issues than at any time in the past decade.

2. Findings from the Project, 2003-2007

We organize the project’s findings into six major areas: empirical, process-oriented, discrete products, theoretical insights, those assessing particular challenges and obstacles, and identification of future research questions.

a. Take-home messages

Overall, the findings reached over the length of the project provide insights on several important topics.

First, all indications from this work are that binational cooperation in the Arizona-Sonora border region in the areas of climate and water, in spite of the documented barriers to such cooperation, is making significant headway via increasing scientific collaboration and joint decisionmaking activities; we expect such progress to continue into the future.

Second, in comparison to five years ago, we have observed a significant increase in capacity built in the realm of climate-water science and society in this region, embodied in the now-solid team of researchers,

water managers, and decisionmakers from both countries who now meet regularly and are determined to better integrate this work.

Third, as a direct result of this project, we are well on our way to developing a fully-functional, binational climate outlook summary product, along with complementary curricular and decision support tools, and the effort will be sustained through additional funding (some already obtained) and through the networks of people consolidated through this process.

Fourth, it is obvious that this region, like other arid regions, will always be constrained by variable precipitation; but it has also been documented through this project that, within this diverse area, vulnerabilities to climate variability will be exacerbated by climate change in distinct ways, and the climate tools developed must respond to variability within these human-environment contexts.

Fifth, though the international border region shared by Mexico and the US poses substantial obstacles to cross-border research and management of water and climate (many of which are documented through this project), this work provides evidence that progress can be made on these topics through a sustained and concerted effort.

Finally, the team of researchers and stakeholders that this current NOAA project brought together has synthesized climate and water science with decisionmaking on key challenges in the border region. A major regional, binational priority identified in the process is intersectoral allocation of water among competing demands in the context of supply variability resulting from climate change. The team we have assembled is pursuing these challenges through a series of newly funded projects and pending proposals.

b. Major empirical findings and developments

Perceptions of climate problems

- Climate is perceived as a contributing factor to—but not the primary reason for—the major water issue: lack of reliable potable water service.
- Persistence of the “desert” thesis among water managers and the public contributes to a lack of willingness to actively engage in climate-related planning and mitigation. The “desert” thesis refers to the oft-expressed notion that “We live in the desert and there’s not much we can do about high temperatures and drought, other than learn to live with it.”
- Climate variability on both sides of the border, especially drought, is of increasing concern to citizens and water managers alike. The impacts of the prolonged drought in Sonora, dating from the mid-1990s, have been experienced and have caused the loss of millions of pesos in cattle die-offs, loss of growing seasons, and the inability to irrigate sufficiently.
- The Arizona-Sonora border region is an area of high vulnerability, due to demographic, socioeconomic and climate factors, including faster than average population growth, a binational population with two languages and governments, lack of adequate resources for planning and adaptation, and reliance on intensive irrigated export agriculture. The deteriorating geopolitical situation between the US and Mexico, in light of the conflation of national security, immigration and drug interdiction policies, presents new challenges to the task of transboundary cooperation.

Climate knowledge / Utilization of climate science products

- Climate science is underutilized on both sides of the border by urban water managers. Water managers state that often the information available is inappropriate or inaccurate for their needs.
- However, urban water managers recognize the growing importance of climate issues on water supply, and therefore desire more climate products. But these climate products need to be appropriate, accurate, timely and accessible.
- Urban water managers in Sonora have very limited access to climate products, beyond near-term (5 day) forecasts and daily precipitation and temperature information. Although water management has formally been “decentralized” to the municipal level in Mexico, climate science knowledge and production remains highly centralized and access is carefully controlled.

- In contrast, urban water managers on the Arizona side have a wealth of sophisticated climate information available online, from universities and extension services, as well as the federal government. Despite this wealth of climate information, several studies show that urban water managers by and large do not utilize climate information in their daily planning and operations.

Water supply, management and pricing issues

- Generally speaking, improving human access to water resources in Mexico is a more critical near-term issue than climate impacts; however extreme events and sustained drought can intensify problems associated with water availability. A combination of infrastructure and bureaucratic problems are the main sources of inadequacy in the water supply system.
- Most people in Sonora are resistant to paying higher water tariffs, and resist individual residential water metering.
- The biggest issue for Mexican citizens is lack of reliable water service, which is frequently available only hours a day, rather than around the clock.
- The reliability of water sources for irrigation is a source of major concern in Sonora, which is the most-irrigated state in Mexico and has an agriculture-reliant economy.
- Water supply and growing water demand are areas that need critical attention, as urban-rural conflicts over water are certain to increase beyond current levels.
- On the US side of the border, political issues dominate the water management agenda; the impacts of climate variability and change are only now starting to reach political agendas in the area.
- Interactions across the international border on collaborative management of the San Pedro River remain weak, but at the same time are central to managing the River for long-term sustainability.

Responses to drought

- Communities in northern rural Mexico experience drought more severely but consider drought a fact of life to which they must adjust, primarily by buying additional water supplies or cutting back on herd or crop size.
- Large agricultural producers in northern Mexico and southern Arizona continue to plant crops requiring more rather than less water, and these crops are irrigated frequently with open canals or revolving irrigators rather than drip systems.

c. Findings on process

Participation of collaborators

- Mexican collaborators are willing to work with NOAA and RISA scientists in this effort. In particular, interested US and Mexican collaborators include Servicio Meteorológico Nacional, NCAR, University of Sonora, IMTA, CICESE, Western Water Assessment, Chihuahua Drought Center at CEISS (Instituto de Ecología A.C.), Southern Regional Climate Center, and California Applications Program.
- The impetus for a border-region climate-outlook product has been very substantially solidified through a series of high-level meetings and scientific exchanges.
- Mexican collaborators are eager to disseminate Border Climate Summary information and garner feedback and support from stakeholders.
- In regard to the theme of this project, science and policy in the water-climate realm, relations among scientists and officials from the two countries around this topic have improved dramatically over the past year and never been stronger.

Collaborative needs assessment

- There is a demonstrated need for binational climate information and forecasts in the study area. A prototype climate outlook product has been developed, but needs further binational support to become operationalized.
- Key applications include water management, irrigated agriculture, fire management, emergency management.

Ongoing, participatory planning

- The 2006 Guaymas conference created a working group for funding strategies and at the meeting itself, more than a dozen such possibilities were discussed in detail. Participants from both countries have arranged to continue discussions with the aim of preparing and submitting joint proposals.
- The 2005 Water Management and Conservation Plan of the Upper San Pedro Partnership recognizes that each town in the Arizona portion of the upper basin needs to include an account of their drought management efforts for their comprehensive general plan. With sustained drought now posing serious problems in Mexico, cross-border linkages appear much more mutually desirable.

d. Discrete products

Education tools

- The curriculum-development team led by co-PIs Margaret Wilder and Anne Browning-Aiken has developed two bilingual educational curriculum units on climate variability and change for primary and secondary schools for use in the Mexico-US border communities. The results of this effort have now been made available to educators in the region and we are receiving requests for guidance with curricula and other advice.
- With new funding from the Sierra Club, ECOSTART II has begun integrating climate components into curricula for teachers in the San Pedro region.
- There is a growing recognition and focus on educating children and young people about climate issues.

The DSS tool

- Demonstration and use of a Decision-Support System model at the Colegio de Sonora and the University of Sonora (as described in a preceding section) have been effective ways to educate specialists who will become water managers and technicians.
- The DSS initiative described in section III.B.4 is now receiving strong attention and appears ready for adoption by academics at UNISON, for eventual use in regional water-and-climate decisionmaking.

The climate outlook summary product

- In close consultation with Mexican climate scientists and officials, the project has developed a prototype output in English and in Spanish, which covers the Arizona-Sonora border region. It is modeled on CLIMAS's successful monthly newsletter (<http://www.ispe.arizona.edu/climas/forecasts/swoutlook.html>), and on its analogue by the Western Water Assessment's monthly Intermountain West Climate Summary (http://wwa.colorado.edu/products/forecasts_and_outlooks/intermountain_west_climate_summary/).

e. Theoretical insights

- The decentralization of Mexican water management is still a work in progress, and is not fully consolidated. Municipal and state water managers lack the financial resources to improve and expand water services—financial resources remain centralized in the federal government.
- The decentralization of Mexican water management has not yet fulfilled the multiple promises associated with the international water management paradigm, of which Mexico is considered a model. Efficiency, equity, local participation and sustainability, among other promises, have not really been achieved. In fact, several studies indicate that the new water management model can lead instead to entrenchment of local elites and stimulate business as usual.
- Despite the shortcomings of the current decentralization strategy, many of the changes associated with the model, such as local participation and river basin councils, are still only in an embryonic stage, and need more time to season and develop.

- Though the US-Mexico border region poses substantial obstacles to collaborative research and management of water and climate, this work provides evidence that progress can be made on these topics through a sustained and concerted effort.
- In particular, focused problems such as climate variability and change can actually help to consolidate cross-border collaboration.

f. Challenges and obstacles

Public awareness and participation

- The creation of Local Drought Impact Groups in Arizona has provided a new venue for discussions and planning climate and water management, but the general public does not seem to know about them.
- Interest and concern about climate change is definitely on the ascent in Sonora at this time. At times within the last three years, however, there has been more limited interest on the part of urban water managers in climate variability and climate change. This is in a sense a definitional issue, since water supply itself is a major concern—but availability of water is not always (and not always appropriately) linked to climate variability/change.
- On both sides of the border, people have a natural tendency to think that if it rains, the drought is over.
- Public education and outreach to schools and communities on both sides of the border about the impacts of drought and climate change and individual responsibility for change are currently lacking. Finding opportunities for outreach in public schools and community meetings is difficult; schools in the US are standards-driven and public meetings have other foci. In addition, finding funding for this type of education and outreach is extremely difficult.

Political obstacles

- Implementing drought planning and climate change discussions at the community level is undercut by the fact that most groups do not have the power to institute water conservation based on drought.
- There is considerable political resistance in the state of Arizona to cutbacks or regulation of population expansion due to drought conditions in the name of “economic development.”
- A kind of limitation for this type of work is the centralized organizational control of CONAGUA (CNA) and its tight control of data and personnel. A principal obstacle has been CONAGUA’s reluctance to provide researchers with more than limited access to meetings and memberships of river basin councils in Sonora. This has somewhat limited the research on river basin councils that the team has been able to do, though there have been substantial findings from these (CLIMAS and NOAA-OGP) projects. If, as it appears, the CONAGUA administration is now opening up to research a bit more, the existing team will take advantage of the opportunity to conduct more interviews and attend consejo de cuenca meetings.
- Relatedly, decentralized management of water and drought planning in northern Mexico moves very slowly; traditional bureaucratic red tape slows down any effort to address these issues jointly.

Capacity

- There is need for greater development of institutions and infrastructure on both sides of the border for long-term monitoring of social as well as hydroclimatological and ecological conditions; this includes development of policies that integrate the results of monitoring and of scientific research, thus facilitating introduction of adaptive management strategies when needed.
- Relatively few professionals in Sonora work on water and climate issues, and an even smaller number belong to environmental groups or are activists (from whom can be sought alternative perspectives to help create more robust results). In addition, there is a scarcity of citizen groups on the Mexican side of the border with whom to collaborate.
- Improvements in institutional mechanisms and water delivery/treatment infrastructure on the Mexican side of the border would be extremely timely and useful.

- Binational collaboration is slow, and bilingual translation is time consuming. There is a lack of bilingual capacity, especially on the American side of the border.

Demand growth

- Climate change, combined with population growth and development, would likely exacerbate existing problems.

g. Lacunae and work to be done

- How can climate knowledge and the utilization of climate science products be stimulated among urban water managers?
- What role can binational cooperation play in meeting the need for decentralized and accessible climate science production and utilization?
- Questions about current and future water supply; uncertainties in the water-climate relationship; uncertainties about growing water demand (e.g., population growth, resort development on the Sonoran coast); uncertainties about the groundwater-surface water interface.
- What are the political challenges in addressing some of these questions (access to data) and informants (e.g., river basin councils, CONAGUA officials)?
- Still more needs to be done to strengthen ties between U.S. and Mexico scientists working on climate change so that there is a more uniform effort at outreach.
- It is important to develop resources for a regularly-issued Border Climate Summary; ongoing work is being funded by the Inter-American Institute for Global Change Research.
- Water managers, policymakers, and scientists should join to find or establish incentives for implementing water conservation for climate reasons.
- Continued human-dimensions research should be conducted on the social, political and economic dynamics of the area, particularly with regard to how these dynamics affect water resources and ecological conditions in the basin.

C. Project outputs

1. Reports to NOAA

University of Arizona. 2006. Interim Progress Report. Tucson: 5 June 2006.

Garfin, G. 2006. Report on the Mexico-U.S. Workshop to Develop a Climate Outlook Product and Stakeholder Decision Support for Northern Mexico, January 10, 2006, University of Sonora, Hermosillo, Sonora, Mexico. Tucson: 28 February 2006.

University of Arizona. 2005. Interim Progress Report. Tucson: 21 July 2005.

University of Arizona. 2004. Interim Progress Report. Tucson: 3 June 2004.

2. Journal articles, book chapters, posters, Web products, and other publications (major publications are preceded by an asterisk)

* Browning-Aiken, A., B. Morehouse A. Davis, M. Wilder, R. Varady, D. Goodrich, R. Carter, D. Moreno, and E.D. McGovern. 2007. Climate, water management, and policy in the San Pedro basin: results of a survey of Mexican stakeholders near the U.S.-Mexico border. *Climatic Change* 85, 3-4 (Dec.) (August online).

* Browning-Aiken, A., H. Richter, D. Goodrich, B. Strain, and R. G. Varady. 2004. Upper San Pedro Basin: fostering collaborative binational watershed management. Special issue of *International Journal of Water Resources Development* 20(3): 353-367. ed. by L. Andersson and D. W. Moody.

* Browning-Aiken, A., R. G. Varady, D. Goodrich, H. Richter, T. Sprouse, and W. J. Shuttleworth. 2006. Integrating science and policy for water management: a case study of the Upper San Pedro River Basin. In *Hydrology and Water Law — Bridging the Gap: A Case Study of HELP Basins*, ed. by J. S. Wallace and P. Wouters. pp. 24-59. In *Water Law and Policy Series*, eds. P. Wouters and S. Vinogradov. IWA Publishing.

- Browning-Aiken, A., R. G. Varady, and D. Moreno. 2004. Water-resources management in the San Pedro Basin: Building binational alliances. *Journal of the Southwest* 45(4): 611-627.
- * Crawford, B. (CLIMAS) and M. Cortez (Servicio Meteorológico Nacional). Border Climate Summary / Resumen del Clima de la Frontera, (Oct. 2006). http://www.ispe.arizona.edu/climas/forecasts/borderoutlook_prototype.pdf. The product was co-developed using the Climate Data and Decision Support System (CLIDDSS; Holly Hartmann, PI).
- Dellinger, E., R. G. Varady, and A. Browning-Aiken. 2006. *Water Policy Research on the San Pedro River Basin: An Annotated Bibliography of Contributions by the Udall Center for Studies in Public Policy, 1997-2006*. Tucson:Udall Center for Studies in Public Policy. 13 pp.
- * Garfin, Gregg. 2007. Listserv: Monsoon Region Climate Applications Listserv. mrca@listserv.arizona.edu.
- * Garfin, G., R. Varady, A. Ray. 2006. Binational collaboration on a North American Monsoon Region Climate information product. B Halvorson, ed., *Extended Abstracts from the Sixth Conference on Research and Resource Management in the Southwestern Deserts: Borders, Boundaries and Time Scales*, May 2-5, 2006, at the Sheraton Hotel & Suites, Tucson, AZ, pp. 47-50. (Published Dec. 2006).
- * Garfin, G., R. G. Varady, A. Ray, M. Cortez Vázquez, C. Watts, M. Montero Martínez, J. Garatuza Payán, C. Arias, W. Alatríste Candiani, D. Gochis, A. López Ibarra, B. Morehouse, H. Díaz. 2006. A bi-national climate information product for the U.S.-Mexico borderlands. Poster at U.S.-Mexico Workshop on Monsoon Region Climate Applications." Sponsored by the NOAA Earth System Research Laboratory. Guaymas, Mexico. 8-12 May 2006.
- * Goodrich, D.C., H. Richter, R. Varady, A. Browning-Aiken, J. Shuttleworth. 2006. The Upper San Pedro Partnership: A case study of successful strategies to connect science to societal needs. *Eos Trans. AGU*, 87(52), Fall Meeting Supplement, Abstract PA31A-0812 (Poster Presentation, Fall AGU Meeting, San Francisco, CA, 11-15 Dec.).
- Goodrich, D. C., E. Z. Stakhiv, A. Browning-Aiken, K. Vache, J. R. Ortiz-Zayas, J. F. Blanco, F. N. Scatena, R. G. Varady, W. B. Bowden, W. Howland. 2005. The HELP (Hydrology for Environment, Life and Policy) experience in North America. *Prdgs. of the EWRI (ASCE Environmental & Water Resources Institute) Watershed Mgt. Conference*. Williamsburg, VA.
- Liverman, D., R. G. Varady, O. Chávez, R. Sánchez, A. Browning-Aiken, and L. Stauber. 2004. Asuntos ambientales en la frontera México-Estados Unidos: Temas y acciones. In *Fronteras en América del Norte: Estudios multidisciplinarios*, ed. by A. Mercado Celis and E. Gutiérrez Romero. Mexico City: Universidad Nacional Autónoma de México, Centro de Investigaciones Sobre América del Norte. pp. 279-293.
- * Morehouse, B.J., D. Ferguson, G. Owen, A. Browning-Aiken, P. Wong-Gonzalez, N. Pineda and R. Varady. In press. Science and socio-ecological resilience: examples from the Arizona-Sonora border. *Environmental Science and Policy*.
- * Morehouse, B. J., R. G. Varady, and M. Wilder. In progress. Collaborative knowledge production for improved water management in the U.S.-Mexico border region.
- * Pineda Pablos, N., A. Browning-Aiken, and M. Wilder. 2007. Equilibrio de bajo nivel y manejo urbano del agua en Cananea, Sonora. *Frontera Norte* 19(37): 143-172.
- * Ray, A.J., G. M. Garfin, L. Brito-Castillo, M. Cortez-Vázquez, H. F. Díaz, J. Garatuza-Payán, D. Gochis, R. Lobato-Sánchez, R. Varady, and C. Watts. 2007. Monsoon region climate applications. *Bulletin of the American Meteorological Society* 88(6): 933-935.
- * Ray, A.J., G. M. Garfin, M. Wilder, M. Vázquez-León, Melanie Lenart, A. C. Comrie. 2007. Applications of monsoon research: Opportunities to inform decision making and reduce regional vulnerability. *Journal of Climate*, May 2007, 20(9): 1608-1627.

- * Richter, H., D. C. Goodrich, A. Browning-Aiken, R. G. Varady. Forthcoming, 2008. Integrating science and policy for water management. In *Ecology and Conservation of the San Pedro River*. Ed. by J. C. Stromberg and B. J. Tellman. Tucson: University of Arizona Press.
- * Rojas-Salazar, C., A. Serrat Capdevila. 2005. Watershed management in the context of climate change: The Upper San Pedro Basin. Poster presented at Encuentro Ambiental. 16-17 May.
- * Rosenberg, N. J., V. M. Mehta, J. R. Olsen, H. von Storch, R. G. Varady, M. J. Hayes, and D. Wilhite. 2007. Societal adaptation to decadal climate variability in the United States. CRCES Workshop on Adaptation to Decadal Climate Variability in the United States, 26-28 April 2007, Waikoloa, Hawaii. *Eos* 88, 43: 444.
- Scott, C.A., F. Flores-López, J.R. Gastélum. December 2007 forthcoming. Appropriation of Río San Juan water by Monterrey city, Mexico: Implications for agriculture and basin water sharing. In Special issue "Transfer of Water from Irrigation to Urban Uses: Lessons from Case Studies" (M. Giordano and Y. Matsuno, eds.), *Paddy & Water Environment*. Springer. 5(4).
- Scott, C.A., J.M. Banister. March 2008 forthcoming. The dilemma of water management "regionalization" in Mexico under centralized resource allocation. *International Journal of Water Resources Development*.
- * Scott, C.A., R. G. Varady, A. Browning-Aiken, and T. W. Sprouse. 2007. Water and energy resources in the Arizona-Sonora border region. *Southwest Hydrology* 6, 5 (Sept.-Oct.): 26-27, 31.
- * Serrat-Capdevila, A., Browning-Aiken, A., Lansey, K., Finan, T. and J.B. Valdés. In completion. Increasing socioe-ecological resilience by placing science at the decision table: The role of the San Pedro Basin Decision Support System Model (Arizona). To be submitted to *Journal of Environmental Management*.
- Serrat-Capdevila, A., J.B. Valdés, J. González Pérez, K. Baird, L. J. Mata, T. Maddock III. 2007. Modeling climate change impacts - and uncertainty - on the hydrology of a riparian system: the San Pedro Basin (Arizona/Sonora), *Journal of Hydrology*, accepted & in press. Published online 17 September 2007.
- * Serrat-Capdevila, A., J. B. Valdes, J. Gonzalez, K. Baird, L.J. Mata, T. Maddock III, and F. Domínguez. 2007. An assessment of long term climate change impacts in a riparian system: The San Pedro Basin. *Eos Trans. AGU*, 88(23), *Jt. Assem. Suppl.*, Abstract H22D-06.
- * Serrat-Capdevila, A., J. B Valdes, J. Gonzalez, K. Baird, and A. Browning-Aiken. 2006. Climate change impacts in Arizona/Sonora: The San Pedro Basin study case. Poster, "U.S.-Mexico Workshop on Monsoon Region Climate Applications." Sponsored by the NOAA Earth System Research Laboratory. Guaymas, Mexico. 8-12 May 2006.
- * Serrat-Capdevila, A., J. B Valdes, J. Gonzalez, K. Baird, and A. Browning-Aiken. 2006. Climate change impacts in Arizona/Sonora: The San Pedro Basin study case. *Proceedings of the Third International Symposium on Transboundary Waters Management*. Ciudad Real, Spain.
- * Serrat-Capdevila, A., J. B. Valdes, J. Gonzalez, K. Baird, L.J. Mata, T. Maddock III (2006), Modeling hydrological impacts of climate change: The case of the transboundary San Pedro Basin, *Eos Trans. AGU*, 87(52), *Fall Meet. Suppl.*, Abstract GC32A-08.
- Serrat Capdevila, A., A. Browning-Aiken, J. B. Valdes, H. Passell, J. Aparicio. 2005. Tools for binational management of water resources: DSS models of the Lower Rio Grande and the Upper San Pedro transboundary basins (poster). Encuentro Fronterizo para el Medio Ambiente. Rosarito, Mexico. 16-17 May.
- * Varady, R. G. and A. Browning-Aiken. 2004-05. Contribution to Good Neighbor Environmental Board annual report, *Water Resources Management on the U.S.-Mexico Border*. Recognition of the impacts of climate variability and human vulnerability along the U.S.-Mexico border under section "Data, Drought and Floods."
- Varady, R. G., and A. Browning-Aiken. 2005. The birth of a Mexican watershed council in the San Pedro basin in Sonora. In *Planeación y Cooperación Transfronteriza en la Frontera México-*

Estados Unidos (Transboundary Planning and Cooperation in the U.S.-Mexico Border Region), ed. by C. Fuentes and S. Peña. pp. 165-183.

Varady, R. G., M. C. Lemos, E. Dellinger McGovern. In progress. Understanding stakeholder processes in the Colorado River Delta region: Policy networks, conservation, and institutional change. To be submitted to a water-resources journal.

Varady, R. G., and B. J. Morehouse. 2004. *Cuanto cuesta?* Development and water in Ambos Nogales and the Upper San Pedro Basin. In *The Social Costs of Industrial Growth in Northern Mexico*, ed. by K. Kopinak. La Jolla, CA: Center for U.S.-Mexican Studies, UCSD. pp. 205-248.

Varady, R. G. and B. J. Morehouse. 2004. Moving borders from the periphery to the center: River basins, political boundaries, and water management policy. In D. Fort and R. Lawford, eds., *Science and Water Resource Issues: Challenges and Opportunities*. American Geophysical Union, Water Resources Monograph No. 16, pp. 143-259.

Varady, R. G., M. Wilder, S. Eden, A. Browning-Aiken, K. Jacobs, and J. Valdes. 2006. 'Mega-networking' at the Fourth World Water Forum in Mexico City: Looking for opportunities at a megaconference. "Guest View" in *Arizona Water Resource* 14(5).

* Wilder, M. Forthcoming 2006. Equity and water in Mexico's changing institutional landscape. In R. Perry, H. Ingram, and J. Whiteley, eds., *Water and Equity: Apportioning Water Among Places and Values*. Massachusetts Institute of Technology (MIT) Press Series on American and Comparative Environmental Politics and Policy.

* Wilder, M. In progress. Implementing a 'New Culture of Water': Transitions in water management in Mexico. Chapter in S. Meijerink and D. Huitema, eds., *Transitions in Water*.

* Wilder, M. 2005. Water, power and social transformation in Mexico: Neoliberal reforms in Mexico. *Vertigo: La Revue de l'Environnement* 6, 2 (September 2005). Montréal: Université de Québec de Montréal.

Wilder, M. and P. Romero Lankao. 2006. Paradoxes of decentralization: Neoliberal reforms and water institutions in Mexico. *World Development*, Vol. 34, No. 11 (November): 1977-1995.

* Wilder, M., R. G. Varady, N. Pineda Pablos, A. Browning-Aiken, R. E. Diaz Caravantes, and G. M. Garfin. In completion. Water management in Mexico's 'New Culture of Water.' Emerging opportunities and challenges for climate science and climate knowledge (to be submitted Nov. 2007 to *Global Environmental Change*).

Wilder, M., and S. Whiteford. 2006. Flowing uphill toward money: Groundwater management and *ejidal* producers in Mexico's free trade environment." In Laura Randall, ed., *Changing Structure of Mexico: Political, Social and Economic Prospects*. New York: M.E. Sharpe. pp. 341-358.

3. Presentations

Browning-Aiken, A. 2006. Challenges to implementing transboundary water planning: A political ecology perspective on recent policy changes, management regimes, and institutional practices in U.S. and Mexico. Presented at Fourth World Water Forum as Local Action with IWRM cross-cutting theme. Mexico City, Mexico. 18 Mar.

Browning-Aiken, A. 2006. Participated in panel "Space-based Water Observations: Alliances for Providing Information Essential for Managing the World's Water Resources." Fourth World Water Forum as Local Action with IWRM cross-cutting theme. Mexico City, Mexico. 20 Mar.

Browning-Aiken, A. 2006. Managing water resources in semi-arid ecosystems along the U.S.-Mexico border: regional responses to climate changes in an Arizona-Sonora transboundary basin. Presented in panel "Current Challenges on the Binational Water Agenda: Regional Responses along the U.S.-Mexico Border," at Association of Borderlands Studies Conference. Phoenix, AZ. 21 Apr.

Browning-Aiken, A. 2006. Experiencias Internacionais de Exploração de Aquíferos: Procurando a Sustentabilidade na Fronteira dos Estados Unidos e México. II Seminário Internacional sobre

- Gestão Social das Bacias Hidrográficas, Florianópolis and Urubici, Santa Catarina, Brazil. 21-26 Nov.
- Browning-Aiken, A. 2006. What are the needs of the rural landscape and the public? Environmental policy and community collaboration. Newcastle University UNESCO EA CHASM. 3-6 Sept.
- Browning-Aiken, A. 2005. Managing water resources in semi-arid ecosystems along the U.S.-Mexico border: regional responses to climate changes in an Arizona-Sonora transboundary basin. "Global Change in Arid Lands," Association of Pacific Coast Geographers conference. Phoenix, Arizona. Oct.
- Browning-Aiken, A. 2005. Presentation on San Pedro basin at Workshop on Options for Use of Climate Vulnerability Index (CVI), sponsored by UNESCO International Hydrologic Programme (IHP)/HELP, Guayaquil, Ecuador, 21-23 March. Organized by R. G. Varady.
- Browning-Aiken, A. 2005. Climate variability and ecosystem impacts in the Southwest: proactive planning for natural resource conflicts. Impacts in Southwestern Forests and Woodlands, Sedona, AZ, 7-9 Feb.
- Browning-Aiken, A. 2004. HELP presentation on the San Pedro (U.S.-Mexico) and Lake Peipsi (Estonia/Russia) demonstrated how in different climatic, ecologic, and national regions, similar issues were raised, such as the importance of establishing trust, sharing information, and the difficulties posed by economic and political asymmetries, Second International Symposium on Transboundary Water Management, Tucson, AZ, 16-19 Nov.
- Browning-Aiken, A. 2004. Invited panelist and presenter on social issues regarding water and climate in the U.S.-Mexico San Pedro basin. Seminário Internacional Sobre Gestão Social De Bacias Hidrográficas (International Seminar on Social Management of Watersheds), Urubici E Florianópolis, Santa Catarina, Brazil. 6-14 Aug.
- Browning-Aiken, A., B. Morehouse. 2006. Managing Water Resources in Semi-arid Ecosystems along the U.S.-Mexico Border: Regional Responses to Climate Changes. Association for Borderlands Studies. Phoenix, AZ. 21 Apr.
- Browning-Aiken, A., B. Morehouse, and R. G. Varady. 2006. Climate, water management and policy in the San Pedro River Basin: Report on Mexican stakeholder surveys . Presented by Browning-Aiken at Seminario Internacional sobre Gestão Social das Bacias Hidrográficas. Urubici and Florianópolis, Santa Catarina, Brazil. 15-20 Nov.
- Browning-Aiken, A., and N. Pineda. 2005. Challenges to implementing Mexican water policy: a political ecology perspective on water resource collaboration, institutional bureaucracy, and local participation" presented at the Society for Applied Anthropology Conference, Santa Fe, NM. Apr.
- Browning-Aiken, A., and R. G. Varady. 2006. Challenges to implementing transboundary water planning: the process of institution building along the U.S.-Mexico border. Presented by Browning-Aiken at the 66th conference of the Society for Applied Anthropology (SfAA). Vancouver, Canada. 31 Mar.
- Browning-Aiken, A., R. G. Varady, B. Morehouse, and A. Davis. 2004. Pioneering a binational dialogue on water and climate: implementing institutional change. Presented at the AWRA & IWLR International Specialty Conference on Good Water Governance for People and Nature, "What Roles for Law, Institutions, Science and Finance?" Dundee, Scotland. 30 Aug.
- Crawford, B. Bi-National Border Climate Outlook Product. In: NOAA Climate Predictors and Applications Science Workshop, Seattle, Washington, March 20-23,
- Garfin, G., 2004. Borderlands Drought. Presentation (invited) to the Good Neighbor Environmental Board Meeting, Douglas, AZ. 17 Oct.
- Garfin, G. Climate Change: Colorado River Basin and the U.S.-Mexico Border. In: Water Education Foundation Mexican Delta Tour. 7 Mar.
- Garfin, G. Climate Change at the Border. In: Border Legislative Conference, Phoenix, Arizona, December 8, 2006.

- Garfin, G., R. Varady, B. Morehouse, M. Wilder, B Crawford. Establishing an ongoing binational U.S.-Mexico border climate diagnostic summary: Developing a prototype and navigating the institutional landscape. Joint Assembly, American Geophysical Union/Mexican Geophysical Union (AGU/MGU). 22 May.
- Goodrich, D. C. 2004. Plenary presentation entitled, "The Dance Between Science, Decision Making, and Public Education for Natural Resource Management." To the Connecting Sky Islands and Desert Seas Conference. Tucson, AZ. 11-15 May.
- Goodrich, D. C., E. Z. Stakhiv, A. Browning-Aiken, K. Vache, J. R. Ortiz-Zayas, J. F. Blanco, F. N. Scatena, R. G. Varady, W. B. Bowden, W. Howland. 2005. The HELP (Hydrology for Environment, Life and Policy) experience in North America. Presented at EWRI (ASCE Environmental and Water Resources Institute) Watershed Management Conference. Williamsburg, VA. 20 July.
- Morehouse, B.J. 2006. Sustainability under uncertainty in arid and semiarid ecosystems: a focus on the Greater Sonoran Ecoregion, Monsoon Applications Workshop, Guaymas, Sonora, Mexico. 8-11 May.
- Serrat-Capdevila, A., A. Browning-Aiken, K. Lansey, and J. B. Valdes. 2007. Feedback from the field: The Stakeholders' take on the DSS model Development Process. Assessing science contributions in the Upper San Pedro Partnership. Annual Meeting of SAHRA NSF Science and Technology Center (Sustainability of semi-Arid Hydrology and Riparian Areas). Tucson, AZ. 10-12 Oct.
- Serrat-Capdevila, J.B.Valdes, J. Gonzalez Perez, K. Baird, Luis J. Mata, A. Browning-Aiken, 2006. Climate change: Coupling hydrologic modeling with policy making. From sustainability to resilience. Presented in the "Water, Ecosystems and Sustainable Development in arid and semi-arid zones" Conference, Urumqi, China. 9-15 Oct.
- Serrat Capdevila, A., and A. Browning-Aiken, 2006. Binational academic collaboration in water management support models: An approach and a tool towards collaborative management in the border area. Paper Presented at The Association of Borderlands Studies Conference. Phoenix, AZ. 21 Apr.
- Serrat-Capdevila, A., J. B Valdes, J. Gonzalez, K. Baird, and A. Browning-Aiken. 2006. Climate change impacts in Arizona/Sonora: The San Pedro Basin study case. Presented at the Third International Symposium on Transboundary Waters Management. Ciudad Real, Spain. 30 May-2 June.
- Serrat Capdevila, A. and A. Browning-Aiken. 2006. Binational academic collaboration in water management support models: An approach and a tool towards collaborative management in the border area. Presented at Association of Borderlands Studies Conference. Phoenix, AZ. 21 Apr.
- Varady, R. G., and A. Browning-Aiken. 2006. Building crossborder alliances in environmental-resources policy and management: Udall Center experiences. Presented at 6th Conference on Research and Resource Management in the Southwest Deserts: Borders, Boundaries and Time Scales. Tucson, AZ. 4 May.
- Varady, R.G., G. Garfin, B. Morehouse, and M. Wilder. 2007. Societal impacts of climate in the Southwest and U.S.-Mexico border region. Presentation for Session III, Climate Impacts Inventory, CR. Joint Meeting, American Geophysical Union/Mexican Geophysical Union (AGU/MGU). Acapulco, Mexico. 22 May.
- Varady, R. G., and B. Morehouse. 2004. Cuanto Cuesta? Environmental costs of development in the U.S.-Mexico border region. Presented at the XXV International Congress of LASA (Latin American Studies Association). Las Vegas, NV. 9 Oct.
- Varady, R., B. Morehouse, M. Wilder, B Crawford. 2007. Climate Change Challenges in the Arizona-Sonora Border Region. In: Arizona-Mexico Commission Water Committee, 2007 Summer Plenary Session. Tucson, AZ. 14 June 14.

- Varady, R. and A. Ray. 2006. Binational Collaboration on a North American Monsoon Region Climate Information Product. In: Sixth Conference on Research and Resource Management in the Southwestern Deserts: Borders, Boundaries and Time Scales. Tucson, AZ. 2-5 May.
- Varady, R, M Wilder, B Morehouse and G Garfin. 2007. Institutions and societal impacts of climate in the Lower Colorado and San Pedro basins of the U.S.-Mexico border region. Paper presented at special session, Transboundary issues in the US-Mexico Border, American Geophysical Union 2007 Joint Assembly, Acapulco, Mexico. 22-25 May.
- Wilder, M. 2008. New Geographies of Climate Change and Environmental Governance on the Mexico-U.S. Border: Institutions, Environmental Organizations, and Local Communities in the Binational Colorado River and Delta Region. Association of American Geographers (AAG), Apr. 2008.
- Wilder, M. 2007. Just Add Water: Implications for Privatization, Sustainability and Development in Mexico's Ejido Sector. Latin American Studies Association (LASA), Montreal, Québec. 5 Sept.
- Wilder, M. 2007. 'Hidden practices' and 'hydrosocial flows:' The political ecology of water in northern Mexico. Udall Fellows Talk, Udall Center for Studies in Public Policy, University of AZ. 8 Mar.
- Wilder, M. 2007. Privatization, Deprivation, and the Construction of Water "Rights" in Rural Mexico. Association of American Geographers (AAG). 18 Apr.
- Wilder, M. 2007. Water, poverty and the Millennium Development Goals. Conference of Latin Americanist Geographers (CLAG), Colorado Springs, CO. 2 June.
- Wilder, M. 2007. Assessing uses and values of riparian natural resources in the binational Lower Colorado and Delta: Preliminary survey results. Binational Lower Colorado and Delta meeting. Tucson, AZ. 15 Ar.
- Wilder, M. 2007. Water in Latin America: Geopolitics, development and future challenges. Presentation to K-12 local Tucson, Arizona teachers for professional development course, "Oil and Water in Latin America and the Middle East," University of Arizona, Tucson. 20 Oct.
- Wilder, M. 2007. Interview on drought and Mexican perspectives on Colorado River allocations and shortages, Canadian Broadcasting Company (CBC) public radio program "Climate Currents." 18 July.
- Wilder, M. 2006. Climate change in regional context. (presented in Spanish). Keynote presentation at U.S.-Mexico Workshop on Monsoon Region Climate Applications. Sponsored by the NOAA Earth System Research Laboratory. Guaymas, Mexico. 8 May.
- Wilder, M. 2006. Collective action in a global world: Local cooperative processes. Latin American Studies Association meeting, San Juan Puerto Rico. 18 Mar. (discussant).
- Wilder, M. 2006. Human dimensions of sustainability. Presented at "Borders, Boundaries and Time Scales: Sixth Conference on Research and Resources in the Southwestern Deserts." Sheraton Tucson Hotel, Tucson, Arizona. 2 May.
- Wilder, M. 2006. Water and the state: Transforming the governance paradigm in Mexico. Latin American Studies Association meeting. San Juan, Puerto Rico. 17 Mar.
- Wilder, M. 2005. Water, governance and the state: Narratives and denouements of decentralization in Mexico. Association of American Geographers Annual Meeting. 9 April.
- Wilder, M. 2005. Contributed to Andrea Ray's presentation at North American Monsoon Experiment (NAME) meeting, Mexico City. 10 Mar.
- Wilder, M. 2004. Invited plenary speaker. Water, power and social transformation in Mexico's water sector. Water in the Americas conference, Quebec, Canada. 10 Oct.
- Wilder, M. 2005. Invited plenary panel speaker, Urban Affairs Association Annual Meeting, Salt Lake City, Utah. 15 April.

Wilder, M. Transformation of the Mexican water sector: Decentralization and evolving water institutions. Conference of Latin Americanist Geographers (CLAG), 2004 Annual Meeting, Antigua, Guatemala. 19-21 May.

Wilder, M. and K. Meehan. 2004. Integrating climate planning in Mexican water institutions," CNA office, Hermosillo, Sonora. 6 May.

Wilder, M., R. G. Varady, N. Pineda Pablos, A. Browning-Aiken, R. Díaz Caravantes, G. Garfin. 2007. New water management institutions in Mexico's 'New Culture of Water': Emerging opportunities and challenges for effective use of climate knowledge and climate science. Joint Assembly, American Geophysical Union/Mexican Geophysical Union (AGU/MGU). Acapulco, Mexico. 22 May.

IV. RELEVANCE TO THE FIELD OF HUMAN-ENVIRONMENT INTERACTIONS

A. Describe how the results of your project are furthering the field of understanding and analyzing the use of climate information in decisionmaking

While the USPP is developing a water budget for average conditions, with recharge and ET (evapotranspiration) figures derived from a calibrated groundwater model, they realize that components of the water budgets will vary from year to year and more detailed accounting must be undertaken to meet the planning requirements under Section 321 Federal Legislation.

We are finding that collaboration with local water managers in Mexico is challenged by the slow pace of decentralization, wherein management authority remains at the federal agency level with little power devolved to the municipal or subbasin level. Thus basin water managers are limited in their participation in a binational basin alliance to address water and climate concerns. Climate information is centralized within the national water agency (CONAGUA) but use of climate science has not yet been well-integrated into decentralized water institutions. The newly-evolving watershed councils (consejos de cuenca) offer a potential opportunity for enhanced utilization of climate science to effect more sustainable environmentally-sound planning at the basin level, but the watershed councils are limited by having little formal authority. The short (3-year) administrative terms of municipal and state water managers (who tend to change with each new political administration at the "mayoral" or gubernatorial level) also creates challenges for sustained collaborations over longer time horizons.

The project is premised on the inseparability of the sociopolitical setting of the use of climate science from the application of that science. Because the two theaters in which this project is taking place—the U.S. and Mexican portions of the same river basin—are so radically different in nearly every way, they afford a fine opportunity to observe the critical human influences on what many scientists and managers once assumed were purely technical, and thus manifestly tractable problems.

The project's findings about resistance to the use of climate diagnostic products, for different reasons in the two countries, strongly confirm the importance of context. In Mexico, especially, we have witnessed first-hand the difficulties of navigating a well-established and change-averse decisionmaking system. The project is a firm reminder that understanding and analyzing the use of climate information varies in each society and to a large degree, in each local setting.

But at the same time, we have learned during the past year that political barriers such as the ones cited above can be overcome through cautious building of relationships, especially ones based on sharing scientific processes and outcomes. By means of deliberately expanding our network, we have been able to overcome some of the difficulties posed by dealing with officials of another country. In short, we have found that cross-border partners in science and research are the best means of communicating with and alleviating the concerns of agency officials.

We have affirmed that information, tools, and instruments are not adopted merely on the strength of their utility or elegance. Instead, successful introduction of such products requires close familiarity with local, national, and transnational issues; institutions; and actors—and in many cases membership or acceptance in the target society. Though inefficient, the only ways to overcome social, cultural, political, and in some cases legal barriers is through dedicated, time-consumptive, relationship-building efforts.

While during the first two years, we found these efforts to be occasionally frustrating, the past year has led to openings and breakthroughs to be exploited over the coming months.

B. Where appropriate, describe how this research builds on any previously funded HDGEC research

- NSF funded research of SAHRA: Kevin Lansey's decision-support system of the San Pedro Basin.
- Coordination with Reg. Integrated Sciences: Integration with the Climate Assessment of the Southwest (CLIMAS) project, University of Arizona, Margaret Wilder, PI. Project: Decentralization and Urban Water Institutions in Sonora, Mexico.
- Current research builds on the capacity-building of a basin NGO the Sonora-Arizona.
- Regional Environmental Association, which has an active role in promoting a binational alliance. An EPA environmental education grant (ECOSTART II) continues water and climate education in basin schools.

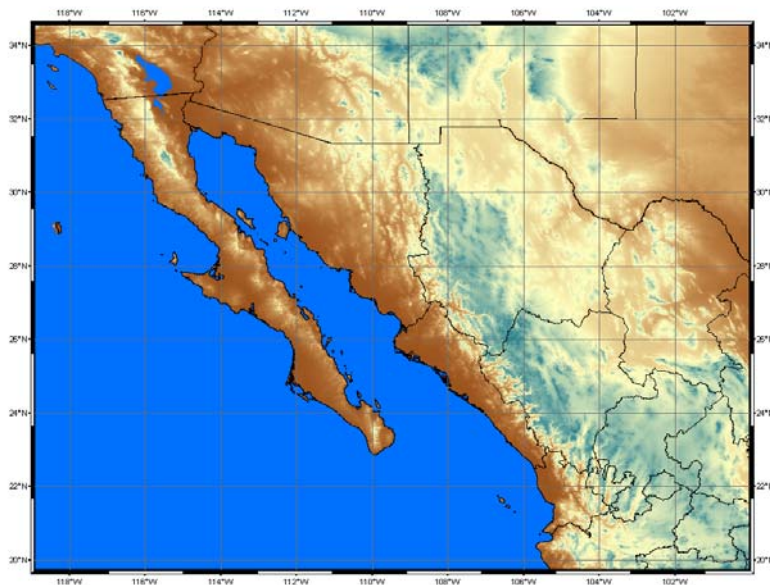
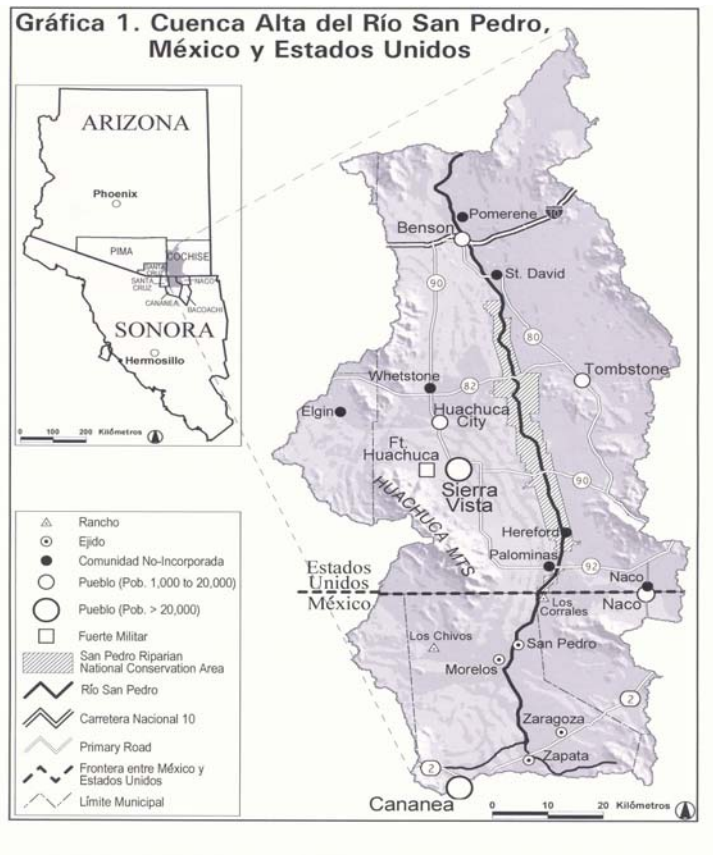
C. How is your project explicitly contributing to the following areas of study?

- Adaptation to long-term climate change: climate and water survey has identified need for climate information and adaptation strategies.
- Natural hazards mitigation.
- Institutional dimensions of global change: meetings with CNA/CONAGUA, COAPAES water managers regarding climate data.
- Economic value of climate forecasts.
- Developing tools for decision makers and end-users: Kevin Lansey's DSS model of the San Pedro Basin.
- Sustainability of vulnerable areas and/or people: The Mexican climate and water survey has established a vulnerability index for the upper part of the basin. The survey calls into question current management practices regarding adaptation to prolonged drought conditions.
- Matching new scientific information with local/indigenous knowledge: The Mexican climate and water survey asked basin residents (rural and urban) about their experiences with climate variability and its impacts on their access to potable water.
- The role of public policy in the use of climate information: The study of Mexican water policy is ongoing because of the current trend toward decentralization of natural resource management to state and municipal levels. However, the process is slow and decisionmaking for the basin remains in the hands of the regional CNA director.
- Socioeconomic impacts of decadal climate variability.
- Other (e.g., gender issues, ways of communicating uncertain information).

D. Photographs from fieldwork to depict study environment

Photos can be provided on demand.

E. Maps: Area covered by study and U.S.-Mexico border region



F. Website addresses for further information

Udall Center for Studies in Public Policy (UA): <http://www.udallcenter.arizona.edu/>

Institute for the Study of Planet Earth (UA): <http://www.ispe.arizona.edu/>

CLIMAS: <http://www.ispe.arizona.edu/climas/>

CLIMAS's monthly newsletter: <http://www.ispe.arizona.edu/climas/forecasts/swoutlook.html>

Prototype binational climate outlook summary product: <http://saturno.fisica.uson.mx/~transfronterizo/>

Center for Latin American Studies (UA): <http://las.arizona.edu/index.html>

SAHRA (Sustainability of semi-Arid Hydrology and Riparian Areas; UA): <http://www.sahra.arizona.edu/>

Upper San Pedro Partnership: <http://www.usppartnership.com/>

APPENDIX I. LIST OF ACRONYMS

ADEQ	Arizona Dept. of Environmental Quality
ARASA	Sonora-Arizona Regional Environmental Association
ARS-GRL	Agricultural Research Service – Grazingland Research Laboratory
ARS-SWRC	Agricultural Research Service – Southwest Watershed Research Center
CEISS	Centro de Investigación Sobre Sequia, at Instituto de Ecología A.C.
CICESE	Centro de Investigación Científica y de Educación Superior de Ensenada
CIAD	Centro de Investigación en Alimentación y Desarrollo
CILA	Comisión Internacional de Límites y Agua
CLAS	Center for Latin American Studies (UA)
CLIMAS	Climate Assessment for the Southwest Project
CLIVAR	Climate Variability and Predictability project of the World Climate Research Programme
CNA	Mexican national water commission / Comisión Nacional de Agua; now CONAGUA
COAPAES	Comisión Estatal de Agua Potable y Alcantarillado de Sonora
COLEF	El Colegio de la Frontera Norte
COLSON	Colegio de Sonora
CONAGUA	Mexican national water commission / Comisión Nacional de Agua; formerly CNA
DICTUS	University of Sonora Department of Scientific Investigations
DSS	Decision support system(s)
ECOSTART	Watershed-based environmental education and exchange program at Udall Center
ENSO	El Niño Southern Oscillation
EPA	Environmental Protection Agency
ET	Evapotranspiration
GEWEX	Global Energy and Water Cycle Experiment
GIS	Geographical information systems
GLOBE Program	Global Learning and Observations to Benefit the Environment, a curricular resource managed by UCAR (University Corporation for Atmospheric Research)
GNEB	Good Neighbor Environmental Board
GPS	Global positioning systems
HDGEC	Human dimensions of global environmental change
HELP	Hydrology for the Environment, Life and Policy program
IBWC	International Boundary and Water Commission
IMADES	Instituto del Medio Ambiente y el Desarrollo Sustentable
IMTA	Mexican National Institute for Water Research / Instituto Mexicano de Tecnología del Agua
INIFAP	Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias
ISPE	Institute for the Study of Planet Earth
IRI/Columbia	International Research Institute, Columbia University
ITSON	Instituto Tecnológico de Sonora
NAME	North American Monsoon Experiment
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NCDC	National Climatic Data Center
NGO	Nongovernmental organization
NRCS	Natural Resources Conservation Service
NSAW	National Seasonal Assessment Workshops (by CLIMAS)
NSF	National Science Foundation
OOMAPA	Organismo Operador Municipal de Agua Potable y Alcantarillado (Naco, Sonora)
PAC	Upper San Pedro Partnership's Partnership Advisory Commission
RISA	Regional Integrated Sciences and Assessments program (NOAA Climate Program)
SAHRA	Sustainability of semi-Arid Hydrology and Riparian Areas
SEMARNAT	Secretaría de Medio Ambiente y Recursos Naturales
SMN	Mexico's National Meteorological Service / Servicio Meteorológico Nacional
SPNC	San Pedro News & Comment
SUUASE	Sustainability Under Uncertainty in Arid and Semiarid Ecosystems

TNC	The Nature Conservancy
TUSD	Tucson Unified School District
UA	University of Arizona
UNAM	Mexican National Autonomous University
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNISON	University of Sonora
USDA/ARS	US Department of Agriculture, Agricultural Research Service
USGS	US Geological Survey
USPP	Upper San Pedro Partnership
WET (Project WET)	Water Education for Teachers, a nonprofit water education organization and publisher of curricular materials
WRAP	GEWEX Water Resource Applications Project
WWA	Western Water Assessment